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OF THE

AMERICAN WELDING SOCIETY

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AMERICAN WELDING SOCIETY

ESTABLISHED 1919

JOURNAL

Volume 3 February, 1924 Number 2

ANNUAL MEETING

The annual meeting of the American Welding Society will be held on April 22nd to 24th. The Meetings and Papers Committee are exerting every effort to make this meeting a success and the greatest in the history of the Society. Some novel features are under consideration including a Smoker at which there will probably be shown a moving picture and also at which there will be provided an opportunity for all of us getting together and in an informal way to discuss the affairs of the Society. As usual an annual dinner and inspection trip will be scheduled. The complete program will be published in the next issue of the Journal.

WORK OF THE AMERICAN BUREAU OF WELDING HIGHLY PRAISED

In addition to acting as the Welding Research Department of the American Welding Society and the Division of Engineering, National Research Council, the American Bureau of Welding has among its membership representatives from some twenty other interested engineering and scientific organizations. One of these is Engineering Foundation to which the Bureau submits annually a report of progress. The representative of the Engineering Foundation on the Bureau is Dr. D. S. Jacobus, Advisory Engineer, Babcock & Wilcox Company. Dr. Jacobus states that those present at the meeting of the Engineering Foundation were considerably interested in the report of the American Bureau of Welding and the Chairman of the Board requested Dr. Jacobus to convey the good will of Engineering Foundation to the American Bureau of Welding and its appreciation of the progress that has been accomplished.

INDEX TO JOURNAL

With this issue each member of the American Welding Society should receive the copies of the Indexes to Volumes I and II of the Journal of the American Welding Society. These indexes have been prepared in order to facilitate references to the papers published by the Society in its Journal.

A few bound volumes are prepared each year which are sold to members at $5.00 per copy and to non-members at $10.00. Members desiring this permanent record should place their order at once before the supply is exhausted.

It is also suggested that these indexes be used in convincing prospective members of the value and benefits which may be derived from joining the American Welding Society.

SOCIETY FACTOR IN EXTENDING WELDING

The influence which the Society exerts in extending the use of Welding is examplified by its recent activities in assisting the Board of Standards and Appeals, of New York City, to draw up a proper code governing the use of welding in the construction of fuel oil storage tanks. In bulletin No. 49 of the Board of Standards and Appeals dated Dec. 4, 1923 there appears under Rule 5 covering "Material and Construction of Tanks for the Storage of Grade A Fuel Oil", paragraph 6 of Section 1, which reads as follows:

"All tanks must be riveted and caulked, or riveted and welded. Flanges or other pipe connections may be welded. All caulking shall be done with round nose tools and without injury to the plates."

This rule does not permit the use of welding alone, although competent authorities agreed that it is not

only reliable but the best process to use in the fabrication of such tanks.

Thru the influence of the Society and individual members thereof this section was completely revised at a public hearing before the Board of Standards and Appeals held on January 28, 1924. These rules provided that all tanks must be welded, riveted and caulked or riveted and welded. Flanges or other pipe connections may be welded. The section dealing with welding is given below.

Much credit is due to the Bureau of Standards which was represented before the Board on several occassions by Professor H. L. Whittemore and also to Mr. Michaels, Engineer of the Fire Prevention Bureau for his industry in guarding the accuracy of the rules prepared under his supervision. There are many installations involving hundreds of thousands of dollars awaiting the enactment of these rules.

Section 4 Welding

(a) Where welding is to be used for a part or for the entire tank, the tank shall be fabricated as required under Rule 5.

(b) All welded seams of plates shall be lapped or butted. When the joint is a lapped joint, the sheet shall be lapped not less than two inches and welded both inside and outside, The plates shall be pulled up tight metal to metal before welding and kept tight together during welding. Both inside and outside welds shall be of full 45 degrees fillet.

Where a butt joint is used, it shall be of 90 deg. double V type welded both inside and outside and reinforced to a total thickness of at least one and one-half times the plate thickness.

(c) All heads shall be flanged, the straight part of the flange being not less than as follows:

For 3/16 inch heads, 1¾ inch flange
For ¼ inch heads, 2 inch flange
For 5/16 inch heads, 2 inch flange
For ⅜ inch heads, 2¼ inch flange

For heads over 120 inches diameter the flange shall be increased in length by one-half inch for each increase in diameter of 2 feet.

Where heads are set into the shell, they shall be a driving fit and the shell shall fit the head closely all around. If of over 1,100 gallon capacity they shall be welded inside and outside with full fillet welds. If of 1,100 gallon capacity or less and not over 48 inches in diameter, welding on the outside only will be sufficient.

Where the heads are butt welded to the shell, the head welds for tanks of 1,100 gallon capacity or less and not over 48 inches in diameter, shall be of the 90 deg. single V type welded entirely through and reinforced not more than one-quarter of the shell thickness. For tanks of over 1,100 gallon capacity the head welds shall be of the 90 deg. double V type welded inside and outside and reinforced to a total thickness of not less than one and one-half times the shell thickness.

(d) Where the tanks are made up of two or more rings the welded longitudinal joints of adjacent sections shall break joints. At no point of a butt girth joint shall the sheet on one side be offset with the sheet on the other side in excess of one-half of the thickness of the plate. All butt girth joints should be welded inside and out and reinforced to at least one and one-half times the plate thickness, except that for tanks of 1,100 gallon capacity or less and not over 48 inches diameter, in which they may be of the same construction as the head seams.

(e) Where braces are welded to the plates the welding shall be done in such a manner as to develop the full net sections of the braces; in other words, the brace will break before the connection will let go.

Braces made in more than one piece shall not be joined together by any method of welding."

FRANCIS JOHN NAPOLITAN

Francis John Napolitan, member American Welding Society died January 6, 1924, in St. Mary's Hospital, Orange, N. J., where he was receiving treatment for abdominal cancer, the malady being disclosed only three months prior to his death.

Mr. Napolitan was Engineer in Charge of the Apparatus Research and Development Department of the Air Reduction Sales Company, under the supervision of Mr. Herman Van Fleet, Vice-President and Operating Manager, at the Company's factories and laboratory in Jersey City.

Few men in the oxyacetylene welding and cutting industry, and none

of his age, had obtained the recognition which was rapidly being accorded him as an authority in the research and development work that has made marked progress in the industry during the past few years. His enthusiasm and broadening experience in both metallography and mechanical design, with the opportunities afforded by connection with an organization that is both prominent and progressive in the industry, seemingly destined him to be a foremost authority in his work.

He acquired valuable practical experience with the oxyacetylene process of welding and cutting, first in the employ of the Cave Welding Company, Springfield, Mass., under the tutelage of Henry Cave, A. S. M. E. a pioneer in the oxyacetylene industry, later coming to the Davis-Bournonville Company, with Mr. Cave, in 1916, continuing with that Company in its Engineering and Research Department until the Davis-Bournonville Company was merged with Air Reduction Sales Company, in 1922, and was with the latter Company until his death.

Mr. Napolitan was born in Bridgeport, Conn., February 8, 1897, and lived in Jersey City, N. J. He married Helen E. McGuire in 1922, and is survived by his wife, his mother, two brothers and one sister of Springfield, Mass.

SECTION ACTIVITIES

Philadelphia

The January meeting of the section was held on the 21st. Mr C. W. Bates presented an address on "The Central Station Company and Welding Industry." The loads of various companies using energy were analyzed including three oxygen producing companies and several large manufacturers of welding parts who made extensive use of electrical energy. It was proven that the gas producing companies actually require twice as much electrical energy as used by electric welding equipment companies.

Chicago

The February meeting of the Chicago Section was held on the 1st. Mr. Henry S. Mann of the Metal and Thermit Corporation presented a paper on the Thermit processes and the uses thereof. He was followed by Mr. K. Llewellyn of the National Tube Company who talked upon the manufacturers of oxygen cylinders. Lantern slides and moving pictures were shown in connection with this latter paper. The meeting was very interesting. About forty were in attendance.

Pittsburgh

The January meeting of the Pittsburgh Section was held on January 5th in the Fort Pitt Hotel. Mr. S. W. Mann of the Welding Department of H. Kleinhaus Company presented a paper on "Precision Welding" which was illustrated by lantern slides. This paper was published in the January issue of the Journal.

New York

The February meeting of the New York Section was held on Feb. 11th. Mr. A. F. Keogh, Manager of the Sound Welding Company presented an interesting paper on "Various Elements That Have to be Considered in Organizing, Financing, Equipping, Managing and Operating a Successful Job Welding Shop". The animated discussion which followed showed the wide interest in this subject by members of the American Welding Society. Mr. C. J. Holslag presented "The View of the Welding Equipment Manufacturers to the Job Welding Shop" and showed some slides of large successful repairs by electric arc welding. About 45 people were in attendance.

Northern New York

The January meeting of the Northern New York Section was held on January 8th in the Edison Club Hall. A paper written by Mr. H. R. Pennington of the Transportation Engineering Corporation of Chicago, who was unable to be present, was read by Mr. Edward W. Bradford of the American Locomotive Company at Schenectady. Mr. Pennington explained the application of arc welding to truck parts of freight cars such as bolsters, couplers, truck sides, coupler bodies and knuckles and described a recommended practice for such repairs. Various points in the papers were illustrated by photographs and blue prints.

Mr. W. M. B. Brady, Arc Welding Specialist of the Chicago office of

the Transportation Engineering Company gave an interesting explanation of the uses to which arc welding may be put in the construction of new locomotives and in the repair of those which have broken in service.

These applications covered the staybolts in new boilers, tender tanks, toolboxes, steam and sand domes, repair of crown sheets, flues and mud rings, frames and moving parts, and attachment of automatic stokers. Each of these various applications was illustrated by slides and complete details as to time required, amount of materials and cost were given by Mr. Brady.

It is interesting to note that the American Locomotive Company has just completed a complete arc welded locomotive tender with a capacity of 15,000 gal. of water and 20 tons of coal. There were about 45 present at the meeting including representatives of the local railroad shops.

The next meeting of the section will be held on February 12th at Schenectady when Mr. E. M. T. Ryder, Way Engineer of the Third Avenue Railway System, New York City, will describe the work which is being done by the Committee on Welded Rail Joints of the American Bureau of Welding.

Cleveland

The January meeting of the Cleveland Section was held at the Hotel Winton on January 15th. This was a joint session with the Cleveland Society of Engineers. Mr. Mills of New York presented an address on "Radio". Smokes were distributed at the meeting.

The February meeting will be on the subject of welding of non-ferrous metals. Mr. C. F. Nagle of the Aluminum Company of America will talk on the aluminum phases of the subject. It is also planned to have a speaker on copper and brass welding.

San Francisco

The January meeting of the Section was held in the Engineers Club on January 18th. Mr. C. A. Britton in charge of the welding at the Moore Dry Dock Company gave some interesting facts from the view point of an experienced welder and conditions which effect the fusion welding industry.

Boston

The January meeting of the Boston section was held on the 11th. Prof. A. S. Kinsey of Stevens Institute and also Advisory Engineer of the Air Reduction Sales Company, presented an interesting lecture on "Cast Iron Welding", illustrated by slides and microphotographs. A new moving picture on "Automatic Acetylene Welding and Cutting of Cast Iron and Sheet Steel", was also presented. The February meeting will be held on the 8th at which time Mr. C. A. McCune, Research Engineer of the Page Steel and Wire Company will present a paper on the "Application of Welding High Carbon Steel". At this meeting Mr. S. W. Miller, Advisory Service Engineer, Union Carbide and Carbon Corporation, will present a paper on the "Development of Acetylene Welding Due to Modern Engineering Research".

The March meeting will be addressed by Mr. W. G. Winsor, Prop., Rhode Island Welding Company in their Providence Plant. The subject will be "The Job Welding Shop"—Its Problems and Their Solutions".

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THE JOB WELDING SHOP SHOULD BE MORE THAN A REPAIR SHOP

S. WADE*

A comprehensive discussion of the job welding business would require a small book, for there are almost as many types of shops and owners as there are welding shops. Frequently, oxy-acetylene welding is done as an adjunct to some other line of business, such as a small machine shop, garage or blacksmith shop. In most such instances, job welding alone does not produce sufficient income to justify a plant devoted primarily to this class of work.

There is a possible and logical explanation for this condition, although there is seldom a real cause for its continuance. The chief reason is that a job welding shop in a small town depends for its work almost entirely on machinery breakdowns—the work is nearly all repair work. In an agricultural community, for instance, the job welder's work for a day will include such jobs as repairing malleable and cast iron parts of farm implements, a few repairs on home utensils, automobiles, etc. But days occur when nothing breaks and there is nothing to weld. Hence, there is a temptation on the part of the owner to look upon the welding equipment as an accessary tool which must wait for work to come to it, and not as an active creator of income.

There are many job welders in small towns who make an active and well planned campaign for new business and are thereby enabled to increase their business appreciably. One of the best fields for selling the job shop's services is found in manufacturing special appliances by the oxy-acetylene process. A community is rarely large enough to support a job welding shop that has not also several other industries. Even agricultural centers have dairy plants, condensed milk factories, grain elevators and canneries. A vast number of these factories are too small to maintain their own welding equipment. Therein lies the job shop's opportunities.

Witness an example of the sort: Lewiston, Mont:, (a town of about six thousand people) is located in a new oil producing country and has one of the state's first oil refineries. At Lewiston is also located the Main Motor Company. In connection with their business of auto repairing a considerable amount of oxy-acetylene welding is necessary. The latter provides a good portion of the shop's income. This is due to the fact, no doubt, that their welding equipment is of the best and their experience qualifies them for almost any kind of welding job.

Recently the local refinery was in need of a special piece of equipment. Knowing that kind of work being done by the Main Motor Company, the refinery manager was easily convinced of the advantages of fabricating the device by the oxy-acetylene process. The part required was what is known as a baffle tower. These towers are used on the vapor line between the oil still and condensing boxes, and serve to separate droplets of liquid from the true gases. The former collect on baffle plates and drain back into the

*Publicity Dep't., Linde Air Products Co.

still. The true gases go through the towers and into the condensers, where they are cooled and converted into a liquid. Briefly such a baffle tower consists of a long vertical cylinder with thin plates like shelves coming from alternate sides. This forces the gases to traverse the tower in a zig-zag path.

As a result of the job-welders recommendations, an initial order was placed with him for eight of these towers. The illustration gives a good idea of the exterior. They were made up from

Fig. 1—Welding Baffle Towers

20 foot oil casings. The 1/8 inch steel baffle plates were put through 3/16 inch slots cut in the casing with a blowpipe. These were dipped downward four inches, and extended to within 2½ inches of the opposite wall of the casing. Holes were cut where specified and 6 inch and 2 inch nipples welded in. The top was cut out and welded to form the dome and a 30 in. square steel plate welded on for the base. Anchor bolt holes were cut in the base plate, and the job was complete. All of the finished towers were tested in the shop and were found entirely satisfactory. Each contained 88 feet of cutting and 30 feet of welding, in which the oxy-acetylene process was utilized exclusively.

Detailed description of these baffle towers is not given with the idea that every shop will find similar work to do, although there may be many such opportunities. It does however, indicate the possibilities of profit for the small job welding shop, if it takes advantage of the opportunities which are open to the enterprising owner.

THE JOB WELDING SHOP *

A. F. KEOGH†

Qualifications of Owner, Manager or Foreman.

The owner or manager of a successful job welding shop must be a welder and be familiar with the various forms of welding. He must be absolutely impartial to all forms and types of welding. He must never have the thought that because he happened to start in the welding field by the electric arc process, that, that is the only type of welding to be employed, or vice versa, if he happened to start in the Oxy-Acetylene or Thermit Process, that he would be commiting a crime to use any other method of welding on a job he knew was unsuited to his process.

Any welder in a shop or any place where welding is used; for his own sake and for the good and advancement of welding, must remember, that every process of welding in use today, has its proper field and is a Godsend to the industry in general. Let us thank those who have worked so hard and so faithfully to develop these processes for us, and also those who are still faithfully giving their best, to improve them.

The next essential is, "Don't be afraid of hard work." If you are, then don't ever start a Job Welding Shop. If you can qualify on the requirements brought out, and if you feel that for the first five years, you are willing to sacrifice your time, patience, nerves, etc, and are willing to work long hours, then you have one more essential in your favor. The Job Welding Shop is a job of sacrifice most times and you are at the beck and call of all whom you serve.

Organization.

I should have mentioned before that I am not trying to use as a model a very large Welding Company but am trying to use as a model a medium, or small sized company to start with. First, we have the Head of the shop, Owner, Manager or what ever we might wish to name him. He should be the man who is familiar with the process, able to estimate and supervise work, have a good mechanical knowledge, (the bigger and broader, the better), have a working knowledge of metals and their characteristics and some ideas of mechanical drawing. He must be fair, honest, trustworthy and above all, human; possess personality and be progressive. Next we have the Foreman, who must be a good welder of varied experience, honest, likeable and fair, also impartial to all processes. He is the man who represents his company a great many times and the impression he leaves on customers, can help or hurt a lot. Next we must have another good welder and if the foreman is a Gas man, than the next man must be Electric, or vice-versa. Then we must have our third man. The choice of this man will always be different among shops. Only time and experience will teach the proper selection, because there are so many things dependent upon him. The type of work and location decides this largely, because

*Presented at the February, 1924, meeting of the New York Section, A. W. S.
†Manager, Sound Welding Co.

in this skeleton organization I am building up, there are many duties to be taken care of that will fall largely upon this third man such as chauffeur, helper, etc. Much care should be given to his selection. Next we must have a combination Book-keeper-Stenographer to handle the clerical work and records. The success or failure of a shop depends a lot on this branch of the business, and no system installed, can be too good. This gives us our organization. Before I go any further, I wish you to know that the success of the shop depends on these men and their honesty in all dealings. Being honest and conscientious, they do good work and their work is your recommendation.

Capital.

This depends entirely on what equipment you desire and how large you want to start. I shall outline the equipment for the type shop I have in mind and then tell you the cost. First is required at least 3 complete sets of Oxy-Acetylene equipment, cutting and welding, next 1 Portable Electric Welding Machine, gasoline driven, 1 one and a half ton truck for equipment and heavy jobs, 1 shop Electric Welding Machine, 1 light car, Ford type for running around and estimating, delivering, supervising, etc., 1 Gas Preheater, 2 Weldng Tables, (1 Elec. and 1 Gas), 1 work bench, 1 Post Grinder, 2 Portable Grinders, 1 Electric Drill, Chain Hoist and Handling equipment and misc. Hand Tools. This does not appear to be much equipment because I have named only the big things. The smaller ones too numerous to mention, yet all of them important and necessary, add to the cost. For this equipment and enough working capital (you must bear in mind that it will take about six months before any money will come in to amount to anything,) you will need about $15,000 to start with.

Location.

As much as I have heard on this subject, it still remains to me a gamble. There is an old adage that says, "Make something good in the wilderness and the world will make a path to your door," but I say, you will make that path yourself, until you and your shop are known, and then the world will widen that path. The only thing I can say about location is, if you want to specialize, get into a district that has the kind of work you want. For instance, for automobile trade, get into the automobile district; heavy machinery, get into the manufacturing or printing districts; for the boiler trades, or tanks, get into the district where they are centralized. Locate with this in mind. New York City is a very good example for this problem, because as a general rule, you will find that practically all of the different industries are situated close together. If general work is wanted, get into a town or district just building up and build with that town or district.

Handling Customers.

There are a great many things that come up in handling customers, and right here it might be said that personality counts as a big factor. You will find some you can never please, but after all, they are human and if you will try to be a little diplomatic and

lend every effort to please, you will find yourself coming out on top most of the time. Of course, the first thing you must do is to win your customer's confidence. There have been in the past, just a few first class and conscientious shops and they have been an asset to the industry in general. They are the ones that remain, but on the other hand, there have been and still are a great number of shops in existance, that are a detriment to the industry because of their inferior workmanship and enormous prices. Due to their inferior work, the public today is very skeptical. When I went out a few years ago to solicit welding service, I was met on every side with remarks such as these: well we don't have any welding done because some time ago we had this or that broken and so and so welded it. We paid so much for the job and the money spent was wasted. We had to throw it away and buy a new one. We lost the time taking it out, reinstalling it and then doing the work all over again. We did not care much about the price but not to have received any satisfaction is what hurt, and since that time we buy new, anything we break as we have lost all faith in welding. We believe all welding and all welders are alike. Now these people unfortunately have had a sad experience with their first job and if on the other hand, they had gone to a good reliable company, the story would have been different. Therefore, you must strive hard to overcome this handicap and it can only be done by honest dealings and good workmanship. There is one thing I would like to see happen among the Job Welding Shops and that is, that they become better acquainted with one another. If the good shops understood one another in a friendly way, I am quite sure there would be much good come from it, because there are many things that are of interest to these shops, that one could be of service to the other and all would benefit from the contact in the end. Let us get together through the common bond of "The American Welding Society," and try to understand one another. It seems odd to me that most shops never know the other fellow and I do not doubt that there must come to each one at some time or other the same thoughts and feelings that come to me and they are, "What kind of person is this man or company, my fellow Job Shop worker". Why not get some of the real feeling which seems to have been lost since our return from France and which caused each in olive drap or blue to call the other "Buddy". Lets get rid of a lot of this mysticism that seems to prevail about a Job Welding Shop and teach the public that it is not a mystery but a highly skilled art and science. By doing these things, we can help each other and advance welding to a far greater degree and we shall all be the happier.

Getting Business.

In all my experience, I have found that there is only one way of getting business and that is, by personal solicitation. After you have tried to convince a man that your shop has the proper men and facilities to handle his work, the next thing is to get his first job, do it well, give him prompt service, charge him a reasonable

price and you are then assured of a customer. I find from my experience, that some of the inferior shops have received jobs and have cut the price to almost nothing, feeling that they were putting out good bait and the customer would return. Sometimes he has, but the cheap price that has gone out as an incentive for his return, has acted as a boomerang. The customer gets his second job done at the same shop and when he is charged for it, immediately compares both jobs according to price, and our foolish shop loses a customer. It would have payed dividends had he played square with both himself and customer at first, by having a standard price. It requires about four or five years to establish a Welding Shop and if you have lived up to high standards during that time, there is no doubt, but what your success will be assured.

Advertising.

This is a matter of opinion, and will require a lot of experience before the best results can be obtained, as all advertising is costly and most of it a gamble. A man starting in business, with limited capital can not afford to gamble, but we all know that it pays to advertise, yet we must pay to find the right kind of advertising. The best and only real advertisement is a satisfied customer.

Handling Outside Jobs.

It has been my experience that this phase of the work can only be handled expediently one way, and that is, when you receive a phone order or any other kind of an order to do work outside of the shop, you should immediately go to see the work yourself or send your Forman to look it over and report whether it is a Gas or Electric Job. If not, you will find that time and money will be lost from this source. As an instance, I was called to the office and yard of a contractor who handles and maintains thousands of dollars worth of equipment. He told me of a broken part of a Steam Shovel and asked me to send an Electric Welding Machine to the other end of town at once to repair it. I asked him if it was Cast Steel. He said "Yes," but to be sure, I shall find out from my master mechanic. He called the master machanic, who verified the statement. I asked him how he knew it to be Cast Steel. Growing quite indignant he said, "I have been in this business twenty years and should know." We arrived on the job and found Cast Iron. After much telephoning, we finally got the large Casting disassembled, brought it to the shop, preheated it, welded it, wrapped it in asbestos, got it back to the shovel 5 o'clock in the morning. When it is an outside job, go and see it first.

Guranteeing Jobs.

This seems to be a bugaboo among shops and I can not see why, it should be. The only reason a man asks for a guarantee, is because he is skeptical. It is his first job. Why should we not guarantee all jobs. If we can not, there is no use in attempting it. We can not guarantee against accidents, nor against abuse, but

we can and should guarantee all work properly done, for we know it is all right and need have no fear of it.

Supplies.

A Job Shop should carry a full line of welding materials, not too much of any and should not be loaded up with excess. You should not listen to Salesmen of inferior companies, telling you they have something cheap and allow them to mislead you and load you up. If a Job Welding Shop will deal with the standard companies who are reliable, they will find they need not carry big stocks of supplies, because these companies maintain a good service and can supply you with a fresh stock in 12 to 24 hours or less according to location, and you are assured of uniform quality and price.

Dealing with Salesmen.

I find no matter how busy you are, you can always greet the salesman with a friendly greeting and hear his story. These men are busy and don't want to waste your time but if they are real salesmen, your time is not wasted, because they are the real messengers of contact in the industry and from them, one can get many little items of interest and ideas that have been carried out elsewhere. Treat them courteously and you both gain from the contact.

Cost Accounting.

A Job Shop must have a cost accounting system to find out where it is going and it is just as essential to a shop as a compass is to a ship. Without it, the rocks are ahead all of the time. One of the wire companies very graciously gives a sample cost card for every individual job, gratis for the asking to their customers, and they are well worth the effort of securing them.

What a Job is Worth.

There is no job that comes into the welding shop that is worth less than one dollar. I can hear lots of criticism of this, but when you figure your overhead, the cost of material, welder and helper's time and how many people handle this account before it is a finished transaction, then you will agree with me. It would be one of the best things that could happen to the Job Welding Shop, if they would all get together and standardize prices. I know of Job Welding Shops who tell customers, they charge $3.00 per hour for welding outside the shop. When they do that, they are cheating themselves and there is no reason for it. In charging for work in the shop, to be fair to all, you must charge time, material, overhead which is a big item, plus profit. The same is true of outside jobs, plus transportation and travel time.

Hazards.

In connection with the Job Welding Shop, there is always the chance of hazards, such as fire, explosion, physical accidents, etc. That is why insurance rates are so high for Welding Shops. Of course all good standard equipment purchased from reliable companies, is made with this thought always in mind, "To do everything to keep accidents down to a minimum." Yet, there is

always something happening unlooked for. For these reasons, the Fire Department, Bureau of Combustibles, demand of you before giving you a Combustible permit, a copy of your Compensation Insurance Policy. A shop must also pass the Fire Department inspection and requirements, which are very rigid, and each welder must have and carry on his person, a permit to operate combustable gases.

Credits.

This is one thing that the shop must watch closely, and can not give enough attention to. It costs money to carry accounts. You have to meet all your bills promptly to stay in business and you want your money promptly too. All shops starting, are very lenient in this respect, and from this, nothing can be gained. When a customer fails to meet his obligations in thirty days to you, you will find out in very few cases, that there is a good reason. I have made the sorry mistake of letting accounts run, but in the end, you lose your customer and your money too. With reliable companies, a regular written order and thirty days is O. K. but ordinarily, get the money C. O. D. and keep your customer.

Extra Help.

There is just one thing more I would like to say and that is, when a shop has a rush, it needs more men, and as you already have your skeleton organization and sufficient equipment, it is very easy to put extra men into this organization. The newspaper gets an "Ad," and the next morning you have an assortment of Welders. Here your trouble starts. It requires great skill to pick the good ones.

Conclusions.

My real reason for writing this paper is to offset any illusions there may be or has been among my fellow welders, who anticipate starting a Job Welding Shop. Another one is, to try to create a better feeling and understanding among Job Welding Shops.

TRAINING COURSE FOR ELECTRIC ARC WELDERS

FOREWORD.

The study of the work of an arc welder was made by the committee on the Training of Operators. The committee has held several meetings at which most of its members were present. The same general principle has been followed as in the case of gas welding. Owing to the wide difference in the equipment and methods used in arc and gas welding, it is necessary to prepare two separate manuscripts, the one having to do with arc welding, and the other with oxy-acetylene or gas welding. *The material in this bulletin relates only to the work of an arc welder.*

The committee has analized the job of an arc welder and classified the material into the information and training which a successful welder must possess in order to become an efficient workman. The information contained in the bulletin will be of service, for the most part, to those who are responsible for the selection of candidates for training and to the instructor in charge of the training.

For the information of the person who is selecting the candidates for training, the text includes a discussion of the qualifications which the trainee should possess.

For the information of the instructor the text includes references to the fundamentals in arc welding, together with a detailed statement of material classified under type welding jobs arranged in the order of difficulty from the standpoint of teaching. It often happens that the best order for teaching does not correspond to the order in which the workman performs the operations.

The instructor should not feel that he is required to set up all of the type jobs suggested, or even that he must of necessity use any of these jobs, but he should appreciate that the type jobs have been selected and arranged in the order of difficulty as an aid to him in arranging a complete training program.

The instructor should feel a responsibility for checking the trainee against the objective for each of the checking levels in order to make certain that the trainee is making steady progress. He should also feel responsible for giving to the student the auxiliary information, knowledge of science, of drawing and mathematics, which has been suggested in connection with the different checking levels.

The text does not necessarily include all of the information which the instructor may feel called upon to give. The committee believes, however, that a mastery of the manipulative skill required to reach the objective in each of these checking levels, together with a knowledge of the related information suggested on the charts, will be sufficient to insure the turning out of men of above average ability. The bulletin is not intended to be a textbook for the information of the student, since it does not undertake to furnish subject matter on electric arc welding, but it does point out the nature of the training required and the nature of the subject matter.

The report would not have been possible without the cooperation

of the employers who so generously permitted the members of the committee to engage in the work.

J. C. Wright, Chairman.
O. H. Eschholz.
A. M. Candy.
C. S. Graef.
G. E. Harke.
G. A. McGarvey.
S. W. Miller.
J. W. Owens.
B. C. Tracey.
H. I. Walsh.
J. Wilson.
C. W. Roberts.
R. G. Mason.

INTRODUCTION

The analysis of the work of an arc welder as given on the accompanying pages, has been prepared with the view toward supplying a need arising in connection with the training of welders. The application of welding and the inauguration of new methods which may be successfully applied has been so rapid that but little information is available for use by instructors in the many classes being organized in both public and private schools.

An analysis of any occupation or trade is not intended to serve as a text or as a source of information which may be regarded as a statement of standard practices or operations for performing the work. The analysis simply presents various type jobs, together with a statement of the operations necessary to perform each job, and the information and skill which the operator must posses in order to be an efficient worker. In the analysis, the committee has classified all welding work into five blocks or major groups, the classification being based upon the kind of metal welded, the use of the carbon arc and upon the operation of cutting. An additional block based upon purely exercise jobs, as preliminary practice work, is included in order that the instruction might not involve the waste of too much material before the operator becomes sufficiently proficient to be placed upon productive work. It is the sense of the committee, however, that the *time given to purely exercise jobs should at all times be limited and that the use of practical work is to be recommended as early as possible.*

The classification of type jobs is, therefore, arranged in the following blocks:

Block 1. Preliminary Practice Work.
Block 2. Welding Steel.
Block 3. Welding Cast Iron.
Block 4. Welding Copper Alloys.
Block 5. Carbon Arc Welding.
Block 6. Arc Cutting.

Block No. 1 on Preliminary Practice Work has been prepared for the purpose of calling attention to the kind of exercises which could best be used to prepare the student for productive work. The extent to which these exercises should be used will depend entirely upon local conditions, and particularly upon the kind of productive work for which the welder is being trained. Owing to the fact that the exercises are progressively arranged, a considerable amount of practical experience will be necessary in many of them before the man will be in a position to complete the exercise. The instructor should therefore, not undertake to give all of the exercises in consecutive order, but should distribute them throughout the period of

training as needed.

For example, Exercise No. 8 calls for welding where the work is in a vertical position. It is generally agreed that the man ought to have had a considerable amount of practical experience on welding in a flat position before undertaking welding in a vertical position. However, when the man has progressed in practical work to the point where he may be expected to undertake welding in a vertical position, he should first be given this exercise in order that he may develop the particular skill which will reduce the likelihood of wasting more expensive parts or equipment.

The instructor should, therefore, carefully plan his whole training program and inject the exercises in the period of training at the particular point where the man will have secured the necessary amount of practical experience that will enable him to readily master the succeeding step which is progressively more difficult.

Within each of the blocks a number of typical jobs have been listed. These jobs were first arranged in a series of "checking levels", a checking level being a convenient point at which it has seemed desirable that the progress of the pupil should be measured from the standpoint of some definite objective to be accomplished. In most cases the checking levels correspond to a specific objective to be attained; in others two or three checking levels have been used in the case of one objective, it being understood at all times that an instructor will feel responsible for checking up his pupils at certain intervals in order to make certain that the instruction has been reasonably well understood and that the student is making the right sort of progress.

Within each checking level a series of type jobs is provided in order of difficulty, with those jobs requiring less skill and knowledge given first followed by those requiring more skill and practice.

It is not expected that an instructor will feel responsible for giving to any one student all or even the greater part of the type jobs suggested. In fact, it is quite possible that he will find it desirable to omit all the type jobs and select in place other jobs which are more applicable to the work for which the student is being trained. He should, however, feel responsible for selecting jobs of similar difficulty in which a similar kind of experience is involved, since in this way the objective will not only be attained, but the auxiliary information, knowledge of science, etc., will apply and the instruction, therefore, will be well-rounded at the conclusion of the course.

The analysis also includes a statement of the auxiliary information covering:

1. A knowledge of stock, such as an ability to recognize different kinds of stock and to know their working properties.
2. The use and care of tools.
3. A knowledge of safety first precautions which should be taken to prevent accidents.
4. How to prepare the work to be welded.

It is difficult matter for the average instructor to know how much related information in the field of drawing, science, and mathe-

matics should be given when instructing students for work in the various trades and industrial occupations. The work of an arc welder involves an elementary knowledge of the electric current, the question of pre-heating, and scientific consideration of contraction and expansion, studies of which could be pursued scientifically or mathematically to a degree far beyond the ability of the student to comprehend, as well as beyond any need which may arise.

It was, therefore, found to be necessary in the analysis to consider the degree to which the student should be given instruction in these subjects in order that the objective for each of the checking levels might be attained. The information suggested under the heading of Science, Drawing, and Mathematics, is, therefore, limited to the amount which the welder should know in order that he may efficiently perform the welding operations and safeguard the work from injury. The analysis does not include the kind of information which would make the welder a research student, or which would enable him to solve problems requiring a broader knowledge of the scientific and mathematical facts in the field of engineering than is indicated.

In conclusion, therefore, the information on the charts can not be regarded as a text-book to be placed in the hands of prospective welders. It can best be used by the instructor as a guide in laying out the course for training. It is recognized that welding has many and varied applications; these applications covering the field of the general welder who engages mostly in repair work, the welder in shipyards, in railroad shops, in structural steel, and in specialized manufacturing. In each case the responsibility is finally placed upon the instructor for the selection and arrangement of jobs in the most effective instructional order and for giving the instruction which will best prepare the worker for a given field.

Under the stimulus of Federal and State Vocational Education Acts, the public schools in most large cities, as well as of many state vocational education systems, are prepared to assist in the training of teachers for work in this field.

The instructor must be a man who is chosen, (1) because of his knowledge of arc welding as it is applied to the particular industry, and, (2) because of his ability as an instructor. Federal and State Vocational Education Acts recognize that many first-class workmen can become good instructors if trained in the art of teaching. Teaching is itself a skilled trade in which the instructor possesses ability and information which enables him to put over to the student both skill and knowledge in the most effective manner. In practically every State, and in most of the large cities, opportunities are available for bringing together from ten to twenty skilled workmen into a teacher-training group, this group oftentimes meeting for a total of thirty to sixty hours to receive instruction in the art of teaching. The instruction includes such things as lesson planning, job analysis, and methods of instruction. The service coming under the above acts is available to industry on request to the proper State or local public school authorities.

I. QUALIFICATIONS FOR WELDERS.

Selecting Applicants for Training. The unique nature of wel-

ding work makes necessary the selection of applicants for training with regard not only to their mechanical fitness for the work, but also with regard to their ability. The character of the work permits of opportunities for unreliable or dishonest workmen to conceal poor or unsound welds, which may endanger human life and property, and prevent a natural development of welding in industrial establishments.

A consideration of the qualifications requisite to success as a welder indicates that some definite procedure can be set up by which it will be possible to give a degree of assurance that a prospective applicant for training either does or does not possess the necessary qualifications.

Failures of greater or lesser importance have occured. These failures may be caused by improper design, improper welding methods, lack of knowledge or failure to realize responsibility, not only on the part of the welder, but on the part of those employing him. It therefore seems necessary for those employing or training welders to see that the applicant has the necessary fundamental qualifications to insure his doing good work after proper instruction. These qualifications are as follows:

a. The presence of a job conscience and of a job pride.
b. The possession of necessary physical qualifications.
d. A sense of responsibility for "safety first."
e. Ingenuity and resourcefulness.

Job Conscience and Job Pride. The presence or absence of a job conscience or job pride can be determined to a certain extent from the knowledge of the occupation previously followed by the applicant. While a successful experience in any occupation may not indicate that the applicant will become a good welder after receiving proper training, yet, on the other hand, the fact that he has successfully worked for satisfactory periods of time in certain kinds of occupations may be taken as a point in his favor which indicates that he will make a good welder in so far as it is necessary for him to be a man who takes pride in his work and who is conscientious.

As an illustration of the above statement, certain occupations are submitted as examples which by their very nature tend to develop on the part of the man the feeling of responsibility. While the occupations given below may not be those from which men aspire to become welders, yet they may be used to illustrate the point in question.

Certain types of occupations are of such a nature that inspection will not show whether the job has or has not been properly done and therefore the responsibility for successful work rests entirely upon the workman. Where a man can show successful experience through a satisfactory period of years in any one of these occupations, we are justified in assuming that he possesses that sense of responsibility known as a job conscience or a job pride.

As illustrations of this group, we have the train despatcher, mail clerk, boiler inspector, elevator inspector, building and insurance inspectors, many railway jobs or occupatons, employees in power

plants, in chemical plants where occupational dangers exist, as well as any occupation which has been followed by craftsmen, the term commonly used to distinguish a skilled worker from the ordinary quantity production worker.

Certain occupations which have grown up as the result of quantity production, by the very nature of the employment leave little responsibility upon the individual workman, since automatic machines and devices determine the quality and often the quantity of the output. Here also little responsibility is present on the part of the worker for ultimate inspection, the inspector being responsible for the quality and accuracy of the output. This group of occupations due to the lack of immediate responsibility placed upon the worker tends to develop very little his sense of responsibility and job pride. Attention is called to the fact that employment in occupations of this type does not of itself necessarily prevent the individual from becoming a good welder, but on the other hand, experience in such jobs is no indication of his having developed the sense of responsibility and job pride which is desirable as a prerequisite to his being trained as a welder.

Experience in training welders does not indicate that mechanical skill in any of the so-called skilled trades is necessary as a qualification for a welder. However, where an individual possesses the other necessary qualifications, experience in these trades is an asset that would assist him in many of the jobs which he is called upon to do as a welder.

In addition to the consideration of the character of the occupation previously followed, attention should also be given to the average length of employment during which the worker held previous jobs and his reasons for changing.

Physical Qualifications. Since welding requires the worker to use his hands and to depend to a certain extent upon his feet in handling all sorts of castings and parts, it is evident that his physical qualifications will enter more or less into the problem of selection. The following qualifications are therefore presented with a statement as to the degree to which they should be considered.

a. *Weight.* The weight makes no difference in the man's ability to do good welding except that a heavy man, particularly if his weight is not due to mere size, is not so able to get into the awkward positions frequently required in welding work. On the other hand, certain types of welding require the lifting of heavy parts in which situation a heavy man would have the advantage.

1. However, it is not advisable for an arc-welder to do the heavy lifting as it is detrimental to the careful manipulation of the electrode.
2. In large shops it has been found desirable to arrange for helpers or chippers to prepare the work for welding rather than to call upon the welder. The above suggestions have been made since the arm muscles should not be fatigued to the extent of impairing the ability to hold a steady arc.

b. *Strength.* For all-around job work or for handling heavy parts, physical strength is evidently an asset, but there are many

welding jobs of a light character in which physical strength is not necessary and which, as a matter of fact, frequently is a liability because of the lightness and delicacy required in such jobs.

c. *Slow or Active.* Great speed of movement does not necessarily mean rapid or good work. A slow man might make every move count and an active one might waste energy by unnecessary motions, so that the question of whether a man is slow or active should be considered in the light of the meaning applied to the words. It is always true that the man who appears slow and who wastes no time, is better in welding work than the man who "fusses and sputters."

d. *Height.* This has no effect on the ability of a man to do any welding job unless in special cases.

e. *Age.* As a matter of general principle the younger man is easier to train than the older one, but this is frequently not true in individual cases, and the older man is more liable to appreciate and understand instructions and to realize the necessity of thought and study in connection with a subject of which he knows very little or nothing. The question of how old a man may be is of less importance than whether or not he is still *mentally and physically flexible* so that he can adjust himself to the requirements imposed upon the welder.

f. *Dexterity.* Arc welding is not as simple as it looks and this qualification is necessary in order that the welder may attain facility in his work. The ability to handle the welding tools with perfect freedom will prevent to a great degree the fatigue accompanying long welding jobs, thus improving the quantity and quality of the work done. A dexterous man will often be able to work in difficult places such as overhead welding where others fail.

g. *Eyesight.* This is possibly the most important physical requirement. Both eyes are necessary. If a man can not see clearly what he is doing, he has no business trying to become a welder. Certain eye defects may be corrected through the use of glasses, but unless the eyesight can be made practically normal in this way the man should not be trained for a welder.

h. *Hearing.* A successful welder should have good hearing. The lack of ability to hear is of greater consequence than the mere ability to receive directions and orders and converse with his fellow beings. There are many noises in the welding shop which defective hearing on the part of the welder would make it impossible for him to recognize conditions affecting his work and his safety.

i. *Nationality.* The influence of nationality upon the qualifications of a welder is more noticeable where the racial habits in that particular nationality are affected by the manner in which they have been accustomed to earn a living. For example, an individual from one of the nations where much industrial development has taken place is more liable to make a good welder than one who comes from a strictly farming, fruit growing, hunting, or other non-mechanical people. It should be noted, however, that the farmer boy from an advanced agricultural district, where much mechanical equipment is used, usually makes a good welder.

j. *Health.* A man to "carry on" successfully as a welder must possess good health. Occupational surroundings are of such a nature as to make this requirement necessary.

k. *Handicaps.* An all-around welder will require the use of both hands and both feet. Certain specialized work, however, may be done by a man who is handicapped by the loss of a leg or an arm.

Mental Qualifications. It is evident that the successful welder should possess certain mental qualifications. Some of these, such as special skill and special knowledge will be supplied during the training period, but for the most part it is expected that the applicant for training will be already mentally qualified. In general, he should possess the following:

a. *Education.* A man should be able to read, write, and speak the English language to an extent equivalent to that covered by a common school education. It is recognized that during the recent war, a number of men who did not possess these qualifications were trained as welders and in some cases they are still employed and making good. These conditions, however, are not the most desirable and as a general rule a man should possess the above qualifications. An elementary knowledge of arithmetic is essential. An all-round welder is called upon at different times to make measurements with precision instruments and to read elementary blueprints, which will require on his part the ability to handle numbers through common fractions and decimal fractions.

b. *General Intelligence.* General intelligence gained through contact with business, through the reading of newspapers, through individual study, through experience in different kinds of work, and through a knowledge of building and construction material, is of great importance to the welder. A man having a broad general intelligence will be able to adapt himself to the many conditions under which he is required to carry on his work.

c. *Mental Quickness.* The ability to observe and react in an emergency or unexpected situation is a necessary qualification for a welder.

d. *Reliability and Carefulness.* The degree to which a man is reliable and exercises care in the performance of his work will measure his success as a welder. It is necessary that his work be always dependable, and that every care be taken not only to prevent injury to the work, to himself, and others, but also to see that the work is done so that there is no future comeback because of failure.

e. *Personal Habits.* Personal habits affect the welder as they affect other skilled workmen. They should be considered in the selecting of candidates to the same degree they are considered in the selection of other skilled workmen.

f. *Adaptability.* A man must be able to adapt himself to all sorts of welding conditions. He will often be required to work in undesirable places and with parts that are unpleasant to handle. The disposition and ability to fit into these situations are of great importance to success in welding.

g. *Alertness.* The fact that there are many varying conditions to be observed during the welding of such jobs as heavy steel plate

would indicate that the welder should be alert, not only to see, but to observe these conditions and act accordingly.

II. SOME OF THE FUNDAMENTALS IN ARC WELDING.

The following discussions of the fundamentals of arc welding have been set up for the purpose of calling the attention of the instructor to certain fundamental information which an arc welder should know before he has completed his course. Some of these fundamentals must be given to him before he is in a position to begin work with the welding outfit. For the most part, however, the instructions should be given to the man just before or during the time when he is at work upon one of the type jobs to which the facts are most nearly related.

Throughout the entire report, the Committee has followed the policy of bringing to the attention of the instructor the character of the instruction needed rather than the content of the instruction. Under this policy the statements made are necessarily brief and merely state a fact without elaboration. By this method the instructor's attention is called to the information, and it is expected that the instructor will give this information to the student.

The subject matter throughout the whole report has been carefully edited so as not to become controversial. The student is more concerned with the elementary facts which will enable him to become a successful arc welder than with differences of opinions in regard to materials, methods and apparatus.

A good instructor will lay out his training program in advance and will carefully plan the lesson from the standpoint of giving instruction to the pupil at the time when it is most needed.

1. Construction and operation of an electrode holder.
   a. Such information as how the electrode holder is constructed, what it is used for, and method of fastening and adjusting electrodes.
   b. Different kinds and sizes of electrodes and their uses.
   c. Such other information as the names of the essential parts of the holder.
2. Construction and operation of an arc welding apparatus.
   a. The measure of electrical energy, terminology, methods of regulating current flow.
   b. General discussion of utilization of electric arc for welding purposes, including a discussion of different arc welding outfits.
   c. Care and operation of equipment. (See Instruction Handbooks furnished by manufacturers.)
3. Difficulties liable to occur in the use of electric apparatus.
   a. As to electrode.
   b. As to generator, transformers, etc.
   c. As to effect on current produced by length of cable and loose connections.
   d. Correct welding polarity and how to test.
   e. Where machine is not kept clean.
   f. Short circuits due to operator leaving electrode holder in contact with work.

4. Difference between metal and carbon arc welding.
   a. Melting the base metal without the use of filler metal.
   b. The use of the carbon arc for cutting.
5. Characteristics of electrodes for welding different metals.

   Attention has been called to these characteristics in connection with the type welding jobs set up in the accompanying charts. The student should be instructed as to the different kinds and sizes of electrodes and the work for which each is intended.
   a. Coated and Covered electrodes and their uses.
   b. Wire for welding steel. (See American Welding Society's Specifications - Bulletin No. 2).
6. Making strength weld test pieces.

   In the preliminary stages of training in arc welding it may be desirable to make a few test pieces in order to show the student the result of poor welding. No special instruction is included covering any exercise process other than that given in connection with the work on type jobs.
   a. Test Specifications of American Welding Society. - Bulletin No. 1.
7. Materials, including:
   a. Recognition of materials.
   b. Working properties.
   c. Chemical differences.
   d. Recognition of alloys.

   It would be better to give most of this information regarding the properties of materials in connection with that part of the instruction which goes with the type job. If given at that time, the student will be able to recognize the different kinds of metals and also how to handle them.
8. Nomenclature and Welding Specifications.

   The instructor is responsible for informing his students of the latest practice which has been agreed upon by recognized authorities, such as is contained in the Journal and Bulletins of the American Welding Society and the Pressure Vessel Code of the American Society of Mechanical Engineers. Further information can be found in the Federal Rules for Steamboat Inspection, in the Report of the Interstate Commerce Commission and in the instructions to inspectors issued by insurance companies and state and municipal authorities.
9. Strength of Pressure Vessels.

   It is important for the welder to appreciate that only the very best welding work be done on all pressure vessels. This appreciation can be secured to a considerable extent by illustrations of good and bad welding, as shown through the use of photographs and test results such as found in the report of the American Bureau of Welding of pressure vessels tested at the Bureau of Standards. - Bulletin No. 5. Definite specifications have been set up in the Pressure Vessel Code of the American Society of Mechanical Engineers for welding pressure vessels.

10. Safety First Principles.

The importance of safety first precautions should be impressed upon the man throughout his entire period of training. This instruction should cover safety precautions relating to the work itself, to the welder, the equipment, and to the other workmen, as well as to the public in general. The uses of safety devices such as shields, helmets, hoods and goggles, (when used by an inspector, crane operator, or by the welder in conjunction with one of the foregoing devices), gauntlets, aprons, and screens for the protection of welders and others should be made a part of the instruction. Information may be obtained from the Board of Fire Underwriters, from bulletins of manufacturers of welding equipment, and from pamphlets issued by the various state and industrial authorities.

11. Use of Precision Tools.

In case a welder is called upon to prepare his work for welding, it will be necessary for him to receive some training in the use of the common machinists' tools. In making accurate welds, it will also be neccessary for the student to understand the use of rules, scales, trams, calipers, dividers, and surface gauges. In some of the type jobs attention has been called to the necessity of rather accurate measurement, and it will be necessary for the welder to use the above measuring instruments to check up his work.

12. Rules and Regulations.

The following list of rules and regulations affect the use of welding and are taken from the second edition of the Welding Encyclopedia and Owen's book on "Fundamentals of Welding." Welders are urged to familiarize themselves with these rules.

A. S. M. E. Boiler Code (1918 Edition) rules for the construction of stationery boilers and for allowable working pressure.

Department of Commerce (Steamboat Inspection Service, Ocean and Coastwise as amended 1922). General rules and regulations prescribed by the Board of Supervising Inspectors' Welding and Reinforcing by the Electric, Oxyacetylene, or other processes.

Lloyd's Register of Shipping Rules.

Various State Rules.

Interstate Commerce Commission - Specifications for Shipping Containers.

American Railroad Association (M.C.B.) Code of Rules.

Steam Boiler and Fly Wheel Service Bureau. Requirements for autogenous welding in insured boilers or other pressure vessels for new construction or repairs.

Underwriters' Laboratories. Standards for construction of stationary acetylene generators, pressure regulators; blow pipes and fitting for oxy-acetylene welding and cutting systems.

National Board of Fire Underwriters - Regulations for the installation and operation of acetylene equipment.

BLOCK NO. 1—PRELIMINARY PRACTICE WORK

Checking Level Number	Type Welding Jobs	Objective for Checking Level	Auxiliary Information 1. Knowledge of stock a. Recognition b. Working properties. 2. Use and care of tools. 3. Safety First. 4. Preparation.	Science Drawing Mathematics
1	**Type Job No. 1** Striking and breaking the arc on a piece of ⅜ or ½" scrap plate, using ⅛ or 5/32" bare low carbon iron or steel electrodes.	1. To properly grip the electrode in the holder and ground the work. 2. To strike the arc without the electrode sticking to the work and the breaking of the arc without causing a deep, spongy, oxydized crater. 3. To develop freedom in the use of the welding arm so as not to depend upon any rigid or body support. 4. To keep the bench or slab clean, so that the exercise plate will lay flat and have a perfect ground.	1. **Stock** No recognition of stock is needed at this beginning period. Student should know the difference between direct and alternating current and the effect of voltage and current values on the behavior of the arc. **Trade Terms** Voltage, current, amperes, voltmeter, ammeter, electrode, electrode holder, generator lead, welding lead, electrode holder lead, electrode receptacle, transformer, motor generator, bending slab, short circuit. **Safety First** Use of gloves, face shield, helmet hood, screens, and the wearing of suitable clothing. Instructor should give elementary instructions as to the occupational dangers due to exposure of the eyes and skin to the rays of the arc, and the necessary instruction bearing upon the protection of neighboring workmen.	1. Preliminary information on: 1. Generation and distribution of the electric current. 2. Transformer and motor generator sets.
2	**Type Job No. 2** Deposit beads in the flat position on a piece of ⅜ or ½" scrap plate using ⅛ or 5/32" bare low carbon iron or	1. To have work clean and free from grease, rust and scale.	Instructor should inform the student by illustrations and examples as to the different kinds of metal that are ordinarily	The arc is approximately 4 to 6 times as hot as the melting point of steel. Electrical and heat conductivity of different metals,

2 (Cont'd)	steel electrodes. Beads should be started on edge of plate remote from the operator and deposited towards the operator. Beads should be about ⅜" apart.		welded by the arc. He should instruct him how to read the ammeter and voltmeter, how to regulate the welding set and the methods of protecting the welding leads and the care of equipment.	e.g., steel, copper and cast iron, vary considerably.
3	**Type Job No. 3** Running adjacent, parallel beads in the flat position on a piece ⅜ or ½" scrap plate using 1/8 or 5/32" bare low carbon iron or steel electrodes. Beads should be started on edge of plate remote from the operator and deposited towards the operator.	To obtain: 1. Fusion of each bead with plate and to adjacent bead. 2. Uniformnity of bead in both height and width. 3. A deposit of clean metal by the use of a wire brush.	Instructor should explain why the plate warps when the deposited metal has cooled.	Both the base metal and the previously deposited metal must be melted to make a weld.
4	**Type Job No. 4** Building up a pad of metal 3"x6"x1" in height in the flat position on a piece of ⅜" or ½" scrap plate, using 1/8 or 5/32" bare iron or low carbon steel electrodes. Beads of each layer should be deposited at right angles to beads of previous layer, and should be commenced at edge of plate remote from the operator, plate being turned on completion of each layer.		**Instructor should explain** 1. Effect of layer direction on tensile strength and ductility of deposit. 2. Annealing effect of each layer on previously deposited layer or layers.	

BLOCK NO. 1—PRELIMINARY PRACTICE WORK—Continued

Checking Level Number	Type Welding Jobs	Objective for Checking Level	Auxiliary Information 1. Knowledge of stock a. Recognition b. Working properties 2. Use and care of tools. 3. Safety First. 4. Preparation.	Science Drawing Mathematics
5	**Type Job No. 5** Same as Type jobs Nos. 2, 3 and 4 except that plate surface is in the vertical position, and in type jobs Nos. 2 and 3, beads are deposited upwards. In type job No. 4 the plate is not turned, alternate layers being deposited upwards and from left to right. Beads deposited from left to right should start at the bottom of the deposit.	To develop ability of student to deposit metal on vertical surfaces.	Instructor should call attention to: 1. The necessity of preferably depositing the metal upwards so as to make a deposit which is free from slag and oxide inclusions. 2. The necessity of having electrode at a suitable angle and using a correct current value.	
6	**Type Job No. 6** Same as Type Jobs Nos. 2, 3 and 4, except that plate surface is in the overhead position.	To develop ability of student to deposit metal on overhead surfaces.	The instructor should explain the necessity of using a short arc, a suitable current value and how the student should protect himself from falling metal.	The theory of metal transfer in the arc and surface tension.
7	Outside corner butt weld made in flat position and formed by the straight edges of two ⅜ or ½"x3"x6" steel plates, placed at right angles along the 6" edge. Joint should be tacked at each end before starting to weld, with bottom edges ⅛" apart. Weld should be made in two continuous layers with $\frac{5}{32}$" bare low carbon iron or steel electrodes, without a backing strip, and metal deposited towards the operator.	To develop ability of student to: 1. Weld two plates together. 2. Move electrode tip so as to prevent slag inclusions in the weld and to secure fusion on both edges of the plate forming the weld. 3. To secure a uniform bead at the bottom of the weld.	The instructor should call attention to the importance of securing uniform penetration at the bottom of the weld and see that enough metal is deposited in the weld. He should explain why high residual stresses will not be found in this form of weld. He should have student fracture all his welds to observe their soundness and progress made.	1. Residual stresses. 2. Various forms of weld and types of joint.

8	**Type Job No. 8** Same as Type No. 7 except that weld is made in the vertical position and the metal deposited upwards.	To develop ability of student to make a vertical weld.	Instructor should have student fracture all his welds to observe their soundness and progress made.	
9	**Type Job No. 9** Same as Type Job No. 7 except that weld is made in the horizontal position. Weld should be started at the left hand end of the joint.	To develop ability of student to make a horizontal weld.	Instructor should explain the necessity of moving the electrode tip so as to deposit metal in the weld with the natural contour produced by the influence of gravity. He should have student fracture all of his welds and observe their soundness and progress being made.	
10	**Type Job No. 10** Same as Type Job No. 7 except that weld is made in the overhead position.	To develop ability to make an overhead weld.	Instructor should have student fracture all of his welds to observe their soundness and progress being made.	
11	**Type Job No. 11** 60 degree double-bevel butt weld in the flat position and formed by two ⅜" or ½"x3"x6" steel plates with a 30 degree bevel along the 6" edge. Joint should be tacked at each end before starting to weld, with bottom edges ⅛" apart. Weld made in two layers with ⅛" bare low carbon electrodes, metal being deposited towards the operator.	To develop ability of student to: 1. Make a weld of double-bevel butt form without melting away too much of the thin edges at the bottom of the weld. 2. To secure a uniform bead at the bottom of the bevel.	The instructor should explain the method of depositing metal by the step-back and intermittent methods and the advantages of each. He may have student make welds 2 to 4 feet long, using these methods. Instructor should have student fracture all of his welds to observe their soundness and progress being made.	
12	**Type Job No. 12** Same as Type Job No. 11 except weld is made in one layer.	To develop ability of student to handle a greater amount of molten metal in the weld without entrapping slag and oxide.	Instructor should stress the importance of correct movement of electrode tip and should have student fracture each weld made.	

BLOCK NO. 1—PRELIMINARY PRACTICE WORK—Continued

Checking Level Number	Type Welding Jobs	Objective for Checking Level	Auxiliary Information 1. Knowledge of stock a. Recognition. b. Working properties. 2. Use and care of tools. 3. Safety First. 4. Preparation.	Science Drawing Mathematics
13	**Type Job No. 13** Same as Type Job No. 12 except that joint is tacked at one end only, the other end being spread approximately ⅜" apart so as to form the semi-rigid type of joint.	To weld a semi-rigid type of joint and on completion of weld have joint edges parallel.	Instructor should explain why one layer is necessary in this type of joint, how to calculate the necessary angular divergence of joint and the mechanical methods used for keeping joint edges apart during welding.	Location and nature of residual stresses in the joint due to the expansion and contraction of the base and weld metals. Angle of divergence of joint edges approximately 1½% of length for ingot iron and steel.
14	**Type Job No. 14** Beads run on a piece of scrap plate with bare low carbon iron or steel electrodes varying in size from ⅛" to ⅝" in diameter.	To develop ability of student to handle electrodes of varying diameters and to become acquainted with correct current values for each size and the relative suitability of each size for welding metal of various thicknesses.	Instructor should impress on the student the commercial necessity of depositing the maximum amount of metal per hour in order to sucessfully compete against riveting and thus advance the art of welding. To do this the student should aim to use largest electrode and the highest current value suitable for each job, even if it is necessary to cool the electrode holder in water or alternately use two electrode holders. Instructor may also have student weld some double-bevel butt and lap joints in ⅜" or ½" plate.	As large an electrode cannot be used for vertical and overhead welding as can be used for flat welding. Two independent drops of water will remain suspended from the ceiling but should they coalesce and become one they drop off.
15	**Type Job No. 15** Beads run on a piece of ⅜" or ½" scrap plate with coated and covered low carbon iron or steel electrodes varying in diameter from ⅛" to ⅝" diameter.	1. To acquaint student with various forms of metal electrodes and their uses. 2. To acquire the special technique peculiar to each form of electrode.	How coatings and coverings are applied to electrode and their composition. Instructor may also have student weld some double-bevel butt and lap joints in ⅜" or ½" plate.	

BLOCK NO. 2—WELDING STEEL

Checking Level Number	Type Welding Jobs (A)	Objective for Checking Level (B)	Auxiliary Information (C)	Science, Drawing, Mathematics (D)
	1.	2.	3.	4.
1	**Building-up operations such as to:** 1. Build up steel valve stems. 2. Build up worn surfaces on couplers. 3. Build up under-machined surfaces. 4. Build up worn flanges. 5. Weld whistle lever holes up to ½" diameter. 6. Weld steel rods up to ⅜" diameter. 7. Weld auto brake lever. 8. Weld shift lever. 9. Weld brake rods (auto or truck) 10. Weld end on lathe dog. 11. Weld handle on tongs. 12. Weld clips for detachable rail stanchions. 13. Build up steel valve stem.	One can successfully deposit metal on steel surfaces which have been properly cleaned and in which the repaired parts require no finishing.	Knowledge of Stock: a. Recognize low, medium and high carbon steel by simple grinding or etching tests. b. Differentiate arc characteristics of various steel electrodes such as globular formation from arc stability and penetration. Use and Care of Tools and Equipment: No further information is necessary at this time. Safety First: Protect others from glare of arc by means of screens and also from contact of hot metal and electric circuit by warning signs.	Reading simple blue prints and making free-hand sketches. Taking off dimensions and interpreting simple conventions. Estimating within an accuracy of 1/16 inch. Electric arc is used for heating metal to above the melting point. The heating effect varies chiefly with the current. Watts = Volts x Amperes.
	5.	6.	7.	8.
2	1. Fill blowholes in steel castings. 2. Fill cracks in steel castings. 3. Fill up holes ⅝" in thickness. 4. Weld trailer guide (building up where worn). 5. Weld angle iron 4"x½" 6. Weld round rods up to 1" in diameter. 7. Weld deck collar. 8. Weld automobile fenders.	One can fill in depression which has been properly prepared previously by chipping and cleaning.	No additional information.	No additional information.

BLOCK NO. 2—WELDING STEEL—Continued

Checking Level Number	Type Welding Jobs (A)	Objective for Checking Level (B)	Auxiliary Information 1. Knowledge of stock a. Recognition. b. Working properties. 2. Use and care of tools. 3. Safety first. 4. Preparation. (C)	Science Drawing Mathematics (D)
2 (Cont'd)	9. Weld wrought iron or steel pipe up to 6" in diameter. 10. Weld side rod grease cup. 11. Weld pressed steel radiators. 12. Weld cup joints, car seat frames gear and pinion sets. 13. Build up worn slide bearing plates.			
3	9 1. Weld rivet heads. 2. Lap weld a small tank up to ⅛" in thickness. 3. Weld assembly holes. 4. Weld spool for brake hanger (build up worn side). 5. Weld truck bolsters and body bolsters. 6. Weld foot on pilot brace. 7. Weld 6" pipe at right angles, making Tee, 90 degree elbow or 45 degree elbow. 8. Weld hatch frame (ship work). 9. Weld engine fly guard (fly wheel). 10. Weld auto truss rod, fender brackets and pedals. 11. Weld pressed steel oil pan. 12. Weld plug in hole in guide bar. 13. Weld dipper latch (where worn) on steam shovel.	10. One can properly weld together two surfaces at right angles, joining them with a single layer.	11. Should be able to: a. Properly prepare bevel and Vee joint for welding. b. Align parts previous to welding. c. Set up prepared parts such as Tees and Ells at proper angle.	12. Two surfaces at right angles require a large concentration of energy, therefore, a higher welding current. (Greater heat conductivity because of greater mass of metal in contact with weld.) Visual measurement of 45, 60 and 90 degree angles. Reading drawings and interpreting nomenclature which indicates the form, weight and continuity of welds.

3 (Cont'd)	14. Weld holes in brake hanger (build up worn place). 15. Weld whistle lever. 16. Weld reverse lever latch (where worn). 17. Weld end on locomotive frame for pilot extension. 18. Weld steel barrels and other steel containers up to ⅛" thickness (not pressure containers). 19. Weld new metal on stoker sprocket wheel where worn. 20. Weld deck rail stanchions to plating. 21. Weld continuous railing rods (joints). 22. Weld skylight over the galley. 23. Weld cargo batten cleats. 24. Weld steel skylights over accommodation spaces. 25. Weld engine room skylights. 26. Weld broken lug or corner on motor casing. 27. Weld worn tire rim lugs. 28. Correct errors in machining. 29. Attach deck collars around ventilators. 30. Attach deck collars around smokestack. 31. Attach cap rings. 32. Attach smokestack pipes. 33. Attach bath and other fixtures in officers' quarters.			
4	13. 1. Weld auto brake lever. 2. Weld shift lever. 3. Weld tanks and steel barrels not over ⅛" in thickness. 4. Weld tooth in quadrant. 5. Weld automobile frame. 6. Weld trailer yoke (center hole worn too large).	14. One can properly weld broken parts or thin sheets without overlapping or preparing edges.	15. One should be able to: a. Properly back up work previous to welding by use of heavy copper block or steel plate. b. Estimate the amount of weld metal deposited per foot of weld.	science: 16. The relative rate of conductivity varies in different metals, e.g., copper, cast iron, steel. By reversing polarity, less energy is developed at the negative terminal. Estimating fairly accurately a circumference by knowing the radius or diameter.

BLOCK NO. 2—WELDING STEEL—Continued

Checking Level Number	Type Welding Jobs (A)	Objective for Checking Level (B)	Auxiliary Information 1. Knowledge of stock. a. Recognition. b. Working properties. 2. Use and care of tools. 3. Safety first. 4. Preparation. (C)	Science Drawing Mathematics (D)
(Cont'd) 4	7. Weld valve yoke (build up to stem where worn). 8. Weld hole in super heater unit pipe. 9. Weld open tanks up to ¼" thickness. 10. Weld pressure vessels up to ¼" thickness. 11. Weld high strength materials on structural steel and rods up to 3" diameter. 12. Build up collars on truck axles. 13. Weld small locomotive frame up to 4"x4" (two man job). 14. Weld joint of super heater unit (where cut out by steam). 15. Weld frame cross brace. 16. Weld crack in end of super heater unit. 17. Weld new joint on superheater unit. 18. Weld teeth in steel gear. 19. Weld end on quadrant. 20. Weld new metal on guide bar (where worn). 21. Weld engine room stairs and grating to plating. 22. Weld boiler room stairs and grating to plating. 23. Weld clips for attaching interior wood finish to casings. 24. Weld coal chutes. 25. Attach galley fixtures to plating.			

(Cont'd) 4	26. Attach cowl supporting rings to ventilators. 27. Attach Bulwark top splicing and end fitting.			
5	17. 1. Weld tanks from ⅛" up to ½", using a double-bevel butt joint. 2. Weld steel rods up to ⅝" diameter. 3. Weld wrought iron or steel pipe. 4. Weld auto truss rods, fender brackets and pedestal. 5. Weld connecting rod for air compressor. 6. Weld key hole in valve stem (fill up where worn too large). 7. Weld crack in side sheet (Loco fire box). 8. Weld trailer yoke (broken in halves). 9. Weld end dipper hanger. Steam shovel. 10. Weld mud ring (cracked in corner). 11. Weld intermediate deck casting. (Cracked) 12. Weld seam in fire door hole. 13. Weld up flat spot in Loco driver wheel tires. 14. Weld mud ring (build up over rivet holes). 15. Weld driver box (cracked through top). 16. Weld pedestal jaws (build up where worn). 17. Weld spoke in main driver wheel. 18. Weld stairs and ladders, including rail attachments. 19. Weld door frames to casings, hinges, catches, etc. 20. Weld butts of W. T. and O. T. boundary bars on bulkheads or floors in double bottom.	18. To properly weld a double-bevel butt joint in a heavy section not to exceed ½" in thickness and can properly prepare a double-bevel joint previous to welding, and if necessary, preheat broken part before welding.	19. One should be able to check the accuracy of repaired parts and finish by grinding.	20. **Science:** Metals, on heating, expand, and on cooling, contract, according to definite laws. Residual stresses are produced in cooling metals which have not been previously preheated and cooled slowly after welding. Determining the amount of contraction based on thickness of metal. Determining the geometrical relation of areas in single-bevel, double-bevel, single-V and double-V joints.

BLOCK NO. 2—WELDING STEEL—Continued

Checking Level Number (Cont'd)	Type Welding Jobs (A)	Objective for Checking Level (B)	(C)	Science Drawing Mathematics (D)
5 (Cont'd)	21. Weld stacks and uptakes. 22. Weld cracked side truck frames, car, tender and traction. 23. Weld feed water heaters and power plant equipment. 24. Weld industrial and dump cars and dredging buckets. 25. Weld motor car and wagon trucks. 26. Weld transformer casing and housings. 27. Build up Lugs on pedestal jaws where worn. 28. Reinforce worn castings, forgings, broken castings, rudder frames, etc. (Ship work).			
6	21. 1. Build up worn axles and keyways. 2. Build up treads on car wheels, and flanges on car wheels. 3. Build up flat spot on Loco drive wheel (bad practice except on yard engine.) 4. Weld tool steel tips. 5. Weld locomotive frame larger than 4"x4". 6. Weld side truck frame. 7. Weld patch on Loco fire box side sheet. 8. Weld connecting rod for air compressor. 9. Weld patch in flue sheet (broken between bridges).	22. To prepare and weld more difficult jobs involving a higher degree of skill. To be able to work on jobs requiring two operators.	23. Should recognize higher carbon content in axle or tool steels. Must be able to thoroughly prepare parts that require preheating, post heating and annealing.	

1. Knowledge of Stock.
   a. Recognition.
   b. Working properties.
2. Use and Care of Tools.
3. Safety First.
4. Preparation.

6 Cont'd	10. Weld new sheets in fire box and new fire boxes. 11. Weld high speed steel cutting tip on lathe tool (Resistance welding best practice.) 12. Weld patch in boiler side sheet. 13. Weld crosshead (cracked through wrist pin hole). 14. Weld crosshead (cracked through piston fit). 15. Weld broken guide yoke. 16. Weld gas engine crank shaft (Emergency repair job only).				

BLOCK NO. 3—WELDING CAST IRON

Checking Level Number	Type Welding Jobs (A)	Objective for Checking Level (B)	Auxiliary Information (C)	Science Drawing Mathematics (D)
1	1. 1. Weld locomotive bell crank. 2. Weld cap for water meter, exhaust manifold lug, tail stock clamp lever. 3. Weld crack in driving box shoe. 4. Weld stove door. 5. Weld furnace shaker. 6. Weld furnace ring. 7. Weld printer's chase. 8. Weld furnace door. 9. Weld piano pedal.	2. To successfully weld broken light cast iron parts which require no special preparation previous to joining and do not require truing or finishing after repairing. (The uses to which these repaired jobs are subjected in this checking level involves no element of danger.)	3. Should recognize characteristics of cast iron compared with other metals such as: 1. Lack of ductility; 2. No appreciable degree of elasticity; 3. High per cent of carbon and manganese. Same precautions regarding care of tools and equipment as mentioned in block on welding of steel.	4. In thin metal less than ¼" the penetration of the arc is sufficient to produce a weld without preparing the joint. On thin metal it is possible to deposit metal fast enough to overcome effect of residual stresses. Plate thickness determines the amount of current and size of electrode to be used.
2	5. 1. Weld lugs on grease collar. 2. Weld flange on C. I. manifold for gasoline engine. 3. Weld lug on pump cylinder. 4. Weld cylinder head on single cylinder gas engine. 5. Weld lug on four cylinder block. 6. Weld broken C. I. scale lever. 7. Weld crack in grease collar.	6. To be able to weld more difficult broken small castings not requiring pressure tight joints and to properly prepare the edges for welding with a double-bevel. (The uses to which these repaired jobs are subjected to in this level involve a slight element of danger.)	8. Welded portion harder on account of absorption of carbon from cast iron. No necessity for reading blue print or making accurate measurements on the jobs in this level.	7. a. Should be able to properly prepare double-bevel joint for welding. b. Should be able to place and use carbon block in backing up work.
3	9. 1. Weld C. I. water back. 2. Weld lugs on driver boxes (cast iron). 3. Weld cable drum where worn out by cable.	10. To prepare and weld more difficult broken castings which require preheating and a certain amount of finishing.	11. Should be able to: a. Properly prepare double Vee joint by chipping or grinding.	12. The expansion of metals is definite, based on changes in temperature. Preheating provides for uni-

(Cont'd) 3	4. Weld 6-in. pump cylinder (cracked from end to end). 5. Weld water jacket for gas engine. 6. Weld cracked jacket on automobile cylinder (1 to 6 cylinders). 7. Weld C. I. vise jaws. 8. Weld water manifold C. I. for gas engine.		b. Align part previous to heating. c. Checking measurements and finishing by grinding.	form contraction and expansion. Reading of scales and dividers in lining and checking up work. Circular measurements, involving diameter, radius, circumference.
4	13. 1. Weld wood working machinery side frames. 2. Weld locomotive cylinder flange. 3. Weld corners of water end of Duplex pump. 4. Weld printing press frame. 5. Weld cylinder head (piece broken out of edge). 6. Weld journal boxes (weld lugs for holding grease cellar). 7. Weld rack for steam shovel (broken in halves). 8. Weld flange on sheave wheel (piece chipped out). 9. Weld punch press frame. 10. Weld sheave base. 11. Weld cylinder valve chamber. 12. Weld tooth in rack for steam shovel. 13. Weld valve chamber for pump. 14. Weld pump cylinder (cracked around flange). 15. Weld gas engine crank case. 16. Weld C. I. belt pulley spokes and rims. 17. Weld C. I. pipe 4" and up. 18. Weld fire hydrants or street light posts. 19. Weld C. I. radiator sections.	14. To weld more difficult parts requiring more skill in setting up and a higher degree of skill in finishing.	15. One should be able in this level to use more skill in preparing parts for welding such as use of: a. Pneumatic chisel in preparing bevel and Vee joints. b. Accuracy in measurement in lining up work. c. More care in finishing. Responsibility of the welder in regard to doing good work because the uses to which these repaired parts are subjected involves danger to life and property.	16. Be able to read simple shop sketches and plan and sectional drawings. Further knowledge of circular measurement involving segments, degrees.

BLOCK NO. 3—WELDING CAST IRON—Continued

Checking Level Number	Type Welding Jobs (A)	Objective for Checking Level (B)	Auxiliary Information (C)	Science Drawing Mathematics (D)
6	17. 1. Weld flange on sprocket case for locomotive stoker. 2. Weld cast iron boiler front. 3. Weld planer bed. 4. Weld C. I. crank case badly broken. 5. Weld patch on radius pipe for Loco Stoker. 6. Weld trailer box (build up where worn). 7. Weld lathe apron. 8. Weld fly wheel (broken spokes or cracked hub or piece broken out of hub, wheel sizes up to 3' diam.). 9. Weld stamping press frame. 10. Weld rims of gear wheels. 11. Weld steam engine cylinders flange broken. 12. Weld steam engine cylinders. 13. Weld cast iron flange on cable drum for hoister engine. 14. Weld frame for hoister engine. 15. Weld centrifugal fan housing (two-man job). 16. Weld hoisting engine drum (two-man job). 17. Weld steam chest on wrecker engine (cracked through stud holes in corners).	18. To weld broken casting requiring more skill and the help of another person in completing the weld.	19. In preparation of broken parts one should be further instructed in the: a. Order of procedure in welding including sequence of deposition of weld metal and the hammering of the deposit to eliminate high residual stresses. b. Drilling and tapping for stud; c. More accuracy in measuring and checking of finished work.	20. Use of studs gives more bearing surface for weld. Further knowedge of use of measuring instruments such as steel tape and calipers.

1. Knowedge of Stock.
   a. Recognition.
   b. Working properties.
2. Use and Care of Tools.
3. Safety First.
4. Preparation.

	21.	22.	23.	24.
6	1. Weld locomotive cylinder. 2. Weld steam chest. 3. Weld steam hammer cylinder. 4. Weld sheave wheel (broken in halves). 5. Weld gear wheel (broken in halves). 6. Weld patch on side of sprocket case for loco stoker). 7. Weld steam cylinder head for air compressor (center broken out, including stuffing box). 8. Weld heater sections (C. I. heat boilers). 9. Weld locomotive valve chamber (studs broken out of both ends at bottom). 10. Weld locomotive cylinder (cracked in bottom). 11. Weld locomotive cylinder (piece broken out of front end). 12. Weld large C. I. press frame. 13. Weld auto crank case where opportunity to machine parts is not at hand. 14. Weld auto cylinder jacket (crack close to bore). 15. Weld C. I. water heater.	One should be able to use judgment regarding preparation of joint edges, proper amount of preheating and caution in cooling or any difficult welding job in cast iron.	Further instruction in preparing broken parts for welding, including use of clamps.	Pressure, pounds per square inch, in closed vessels. Reading simple blue prints in which all dimensions are given. Computing contents, circular and rectangular.

BLOCK NO. 4—WELDING COPPER ALLOYS

Checking Level Number	Type Welding Jobs (A)	Objective for Checking Level (B)	Auxiliary Information (C)	Science Drawing Mathematics (D)
1	1. 1. Weld end on globe or gate valve stem. 2. Weld end of valve stem (build up end for new fit). 3. Weld sand hole in small casting; 4. Weld crack in globe valve body. 5. Weld small brass levers and handles. 6. Weld end on glove valve bonnet. 7. Weld small brass castings broken or cracked. 8. Weld hole in feed pipe. 9. Weld copper pipe at splice. 10. Weld copper heater coils. 11. Weld brass water heater segments.	2. Welder becomes acquainted with behavior of various copper alloys under action of the arc. Also becomes familiar with effect of fluxes.	3. Knowledge of Stock: a. Recognize composition of material to be welded. b. Recognize difference in graphite and carbon rods. c. Safety first: Protect self and others from fumes of volatilized zinc.	4. Reading simple blue prints and shop drawings. Understanding action of fluxes and melting action of copper alloys.
2	5. 1. Weld end on line check valve. 2. Weld crosshead gib (lug broken of), or add metal to take up end play. 3. Weld crack in lubricator body. 4. Weld new metal in hole for lubricator filler plug (threads stripped out). 5. Weld barrel of test pump to base. Brass.	6. Welder becomes experienced in laying down a homogeneous deposit of weld metal free from porosity.	7. No additional information.	8. No additional information.
3	9. 1. Weld crack in ignition body or lubricator or condenser.	10. Welder is able to get perfect fusion, arrange for contraction and expansion	11. No additional information.	12. No additional information.

	2. Weld bronze impeller for centrifugal pump. 3. Weld auto wheel circulating pump. 4. Copper air chamber for water pump, bursted from end to end.	and eliminate porosity and slag inclusions.			
3 (Cont'd)	5. Weld end joint on injector steam pipe. 6. Weld patch on copper branch pipe. 7. Weld bronze propeller tip. 8. Build up engine brasses. 9. Fill shrink hole in bronze propeller. 10. Weld 12" brass flange on copper pipe. 11. Weld whistle bell (cracked). 12. Weld crack in locomotive bell. 13. Weld up steam valve seat in Hancock injector. 14. Weld bell for safety pop (cracked). 15. Weld brass or bronze grids having broken or cracked members (or similar restrained welds). 16. Weld very heavy and large brass castings such as certain types of Diesel engine cylinder heads or other large copper alloy castings. 17. Weld brass plates in powder passing scuttles. 18. Weld brass to steel structural shapes. 19. Weld brass bearing rings on propeller shafts. 20. Weld joints in brass deck plates. Build up deficient flanges on bronze sea stools.				

BLOCK NO. 5—CARBON ARC WELDING

Checking Level Number	Type Welding Jobs (A)	Objective for Checking Level (B)	Auxiliary Information 1. Knowedge of Stock. a. Recognition. b. Working properties. 2. Use and Care of Tools. 3. Safety First. 4. Preparation. (C)	Science Drawing Mathematics (D)
1	1. Cutting off bolts, nuts and rivets. 2. Cutting out bushings both steel and cast iron. 3. Cutting out cracks in preparation for welding. 4. Cutting steel and cast iron. 5. Preheating with carbon electrode.	To familiarize the welder with the control of the carbon arc flame and to show him the results obtained by the various arc lengths.	1. Safety first to operator and others. 2. Protection of eyes, the body, and wearing apparel from ultra-violet rays. 3. Recognition of the different metals and arc requirements for the same. 4. Construction and use of the carbon electrode holder. 5. The results of improper connection and of improper polarity.	1. Methods of determining positive and negative poles of his leads. 2. Electrical units, such as amperes, volts and ohms. 3. Use of resistance for controlling an electrical current. 4. Operation of control panel or switch boards. 5. Types of motor generator sets suitable for carbon-arc welding. 6. Need for good electrical contacts.
2	1. Plugging holes up to 2" thick in flat work, such as— a. Brake equalizers, b. Truck spring hangers, c. Truck frame, d. Brake levers. 2. Building up operations, such as: a. Restoring worn surfaces to original thickness, b. Slide and spring equalizers, c. Mudring supports and clamps, d. Main brake equalizers and bearings.	To familiarize the welder with the use of the filler rod and the carbon electrode.	The instructor must enable the welder: 1. To differentiate between melting of the filler rod or melt bar and the base metal and the proper fusion of the base metal for welding. 2. Difference in appearance and results of burned or crystallized metal, slag properly welded metals. 3. Relation of currents used to size of carbon electrode.	1. Relative melting temperatures of welding rods and base metal. 2. Short circuits due to carelessness in handling electrode and due to worn or broken insulation on leads. 3. Operation of circuit breakers.
3	1. Plugging holes up to 3" diameter and to 4" thickness, such as— a. Truck radius bar, b. Spring equalizers and hangers, c. Brake pull rods.	To be able to control the molten metal from the filler rod, in building up operations up to and including ½" of deposited metal.	1. First aid treatment for flesh burns. 2. Use of eye-washes in eyes when affected by arc "flash."	1. Read simple working drawings such as pencil sketches and shop blue prints. 2. To take off and check his measurements, using

3 (Cont'd)	d. Spring guards and beams. 2. Building up operations, such as— a. Half soling spring beams, b. Lengthening spring saddles, c. Building up truck center castings, d. Trailer boxes and guides.	To recognize the perfect welding arc and the proper procedure to insure a perfect weld.		steel rule graduated to ⅛". 3. The use of calipers (inside and outside) for getting measurements.
4	1. All welding jobs that require clean, solid metal, complete fusion and penetration, and a machinable surface, such as— a. Building up on locomotive crossheads, guides, link parts, stoker parts, frame sections, punch press dies, various machine parts, and boiler mud-rings.	Welder must be able to control molten metal in all building up operations.	1. Care and upkeep of tools and equipment. 2. Necessity of applying sufficient metal in a uniform layer for machining surface. 3. Unnecessary cost due to excessive metal, poor methods, delay in getting repaired part, power consumed, and too much "lost motion."	1. Lining up work by the use of parallel bars, level and steel square. 2. Read dimensioned drawings of machine parts. 3. Gauge and provide for the expansion and contraction of metal parts.
5	1. Building up operations and welding of steel casting, the forming of iron or steel parts including the welding of: a. Guide yokes, truck frames, b. Driving boxes, trailer boxes, c. Trailer guides, truck transoms, d. Truck frames, chafing castings, e. Truck and car bolsters, f. End frames, journal boxes. 2. Building up operations, such as— a. Chafing castings to template, b. Stoker and reverse lever guides, c. Crosshead guides when worn, d. Cast iron spring buffers built up to template.	The welder when completing these jobs should be able to make good welds on all jobs for which the carbon-arc is best adapted.	1. Establishing arc so as to be able to machine part. 2. Importance of being careful so as to avoid "arcing" any part of the surface which is not to be welded. 3. Methods used in machining surface. 4. Preparation of work for welding. 5. More difficult jobs are prepared by machinists.	1. Use of dividers, surface gauges and steel squares. 2. Use of templates and forming gauges. 3. Current carrying capacities of cable leads. 4. Use of trams and straight edges. 5. Measurements to 1/64".

BLOCK NO. 6—ARC CUTTING

Checking Level Number	Type Cutting Job	Objective for Checking Level	Auxiliary Information 1. Knowledge of stock. a. Recognition. b. Working properties. 2. Use and care of tools. 3. Safety first. 4. Preparation.	Science Drawing Mathematics
1	1. Cut ⅛" structural steel or plate. 2. Cut ¼" structural steel or plate. 3. Cut ½" structural steel or plate. 4. Cut 1" structural steel or plate. 5. Cut ⅛" cast iron section. 6. Cut ¼" cast iron section. 7. Cut ½" cast iron section. 8. Cut 1" cast iron section. 9. Cut 1" copper section. 10. Cut 2" copper section. 11. Cut 3" copper section. 12. Cut ½" brass section. 13. Cut ¾" brass section. 14. Cut 1" brass section.	To successfully direct the arc along a given path and make a reasonably straight cut.	Knowledge of Stock: a. Recognize thickness of material which determines current required to make a given cut in a certain length of time. b. Difference in behavior of carbon electrode and graphite electrode. Use and Care of Tools: Keep electrode properly pointed. Safety First: Protect others from glare of arc and contact with hot metal.	Reading simple blue prints and making free-hand sketches. Taking of dimensions and interpreting simple conventions. Estimating within an accuracy of ⅛". Electric arc is used to heat metal to temperature above the melting point. Heating effect varies directly with the amount of current used.
2	1. Cut small risers from castings. 2. Clean out blow holes in castings. 3. Clean out sand holes in castings. 4. Cut scrap steel castings to charging box size. 5. Cut heavy cast iron scrap castings to charging box size. 6. Cut heavy cast iron slag formation around smelters. 7. Cut heavy copper slag formation around cupola.	To successfully handle larger electrodes and higher current values required for cutting heavy sections.	No additional information.	No additional information.
3	1. Cut side sheets in locomotive fire box. 2. Cut stay bolts in locomotive fire box. 3. Cut bolts on R. R. frogs. 4. Cut nuts off R. R. frogs.	To direct the arc more accurately than is required for cutting heavy castings.	No additional information.	No additional information.

	1. Cut steel freight car into sizes suitable for shearing. 2. Cut rivets in steel freight car. 3. Cut rivets in structural steel. 4. Cut rivets in scrapping battleships. 5. Cut shell plating in scrapping battleships. 6. Cut steel framing in scrapping battleships. 7. Cut ends off broken rails for yard service.	To direct the arc and concentrate it on rivet heads without damaging the surrounding plate material.	No additional information.	No additional information.

PROGRESS REPORT No. 2 OF COMMITTEE ON WELDED RAIL JOINTS.

A Summary of Tests to Date

JANUARY, 1924.

Organization.

The American Electric Railway Association and the American Bureau of Welding (The Bureau is the welding research department of the American Welding Society and the Division of Engineering, National Research Council), united in an authoritative investigation of various types of welded rail joints in commercial use through a thoroughly representative Committee which was organized late in 1921. This Committee has a membership of about sixty individuals including Way Engineers of several of the larger street railway companies, representatives of manufacturers of welded joints and welding equipment, welding experts, scientists and testing experts.

The solution of the problems involved requires cooperation on a large scale. Electric Railway Companies all over the country are installing thousands of joints every year and in many cases are using methods and variations in processes the value of which has not been determined.

Dr. G. K. Burgess then head of the Division of Metallurgy, Bureau of Standards, and now Director of the Bureau of Standards was elected as Chairman. Mr. E. M. T. Ryder, Way Engineer of the Third Avenue Railway System was selected Vice-Chairman and Mr. W. Spraragen, Secretary of the Division of Engineering and the American Bureau of Welding was appointed Executive Secretary. Inasmuch as it was impossible to have this large Committee meet more than once or twice a year, the administration of the affairs of the Committee were left in the hands of a small representative Executive Committee.

Relation of American Electric Railway Engineering Association and Committee.

About $24,000 was contributed by the American Electric Railway Association, interested manufacturers, and a number of the larger street railways. The Association is acting as Treasurer for the funds. Expenditures are made upon authorization of the Executive Committee and the bills are countersigned by the Secretary and Vice-Chairman of the Committee and by a member of the Executive Committee of the American Electric Railway Engineering Association.

Review of Present Practices.

In order to compile a summary of the "present state of the art," a questionaire was prepared on five types of joints in commercial use (cast, butt, bar, electric seam, and thermit welded joints) and members of the Committee circularized. Answers to the questionaire were correlated and a progress report of 73 pages printed in May, 1922. Typical problems needing further investigation were also included in the report.

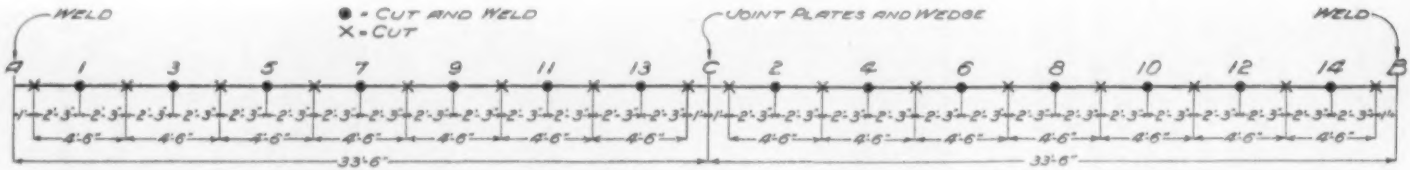


Fig. 1

ALL CUTS TO BE MADE WITH HACK SAW
CONSULT INSTRUCTION SHEET FOR WORKING DETAILS
FILL OUT DATA SHEET AS SOON AS JOINTS ARE FINISHED

INSTRUCTIONS FOR MAKING JOINTS

Welding Test Joints

Method to be followed in making test joints on special rail in order to have the work done under conditions approximating normal track methods as closely as possible.

Two 33′ 6″ rails furnished by Steel Companies for purpose of making test welds are to be laid end to end in existing track after removal of existing rail, and 15″ of pavement each side of the rail and down to the top of the ties. This is to insure that conditions for the workmen making welds are normal and that the temperature conditions are normal including the ability of the adjoining rail to conduct heat and electric current.

Test rails are to be spiked to the ties and the outside ends welded to the adjacent rails. The joint between the test rails is to be fastened with standard bolted plates with ½″ open joint to permit wedging the test rails together at the individual joints as each is cut and welded.

Fig. 5 shows the position and order in which welds are to be made. This has been arranged so as to provide test specimens 4′ 6″ long with the weld in the center, and so as to avoid making the welds consecutively which would introduce abnormal temperature conditions during the work.

Marking

An identification number is assigned to each company making test welds. Each weld is to bear this identification number and also be numbered individually as shown on the diagram. All numbers are to be printed on the web of the rail on opposite sides, and at opposite ends of the test specimens. 12 rails are required for the first set of tests, and the plan outlined on the diagram provides for 14, giving two extra in case of failure in making any of the first twelve.

Data Sheet

A data sheet is to filled out in duplicate for each type of joint according to the forms furnished. The numbers on the data sheet should correspond with those on the specimens.

Objects.

The primary object of the Committee is to improve each type of welded rail joint rather than to make comparative tests on the relative merits of the different types of joints.

Preliminary Program.

It was agreed that the first step was to determine the "present state of the art" in making the different types of welded rail joints, thru suitable tests of each type made by representative street railway companies and by the manufacturers of each type of joint. It was decided to make tensile, drop, repeated impact, bend and conductivity tests on each type of joint. In order to distribute the work it was decided that the Bureau of Standards should make conductivity, repeated impact, and tensile tests and also metallurgical examinations. Purdue University was to make bend and conductivity tests and the University of Illinois the drop tests.

Rails for Specimens.

Rails for the preliminary program were manufactured without charge by the Lorain Steel Company and by the Bethlehem Steel Company and shipped at their expense to the various people who agreed to make up the test joints. Most of the joints have now been completed and shipped to the laboratories.

Rails were specified to be A. E. R. E. A. standard 7" Girder rail rolled to A. E. R. E. A. specification, Class B.

Ladle analysis of the Lorain rails is carbon .75, silicon .16, phosphorus .02, manganese .69.

The analysis of the Bethlehem rails is, carbon .74 to .79, manganese .84 to 87, phosphorus .026 to .029, sulphur .06, silicon .19 to .20.

DATA FURNISHED BY MAKERS OF JOINTS.

A data sheet specifying the information to be recorded in the preparation of joints and in welding was sent to each Company selected to make tests joints. A condensed statement of the information received is included in this report as Appendix A.

TENSILE TESTS

Test Procedure.

In order to enable the Bureau of Standards to make tensile tests in their large Emery Testing Machine without machining the ends of each specimens it was found necessary to design two auxiliary heads. The heads were designed and the wedges furnished by the Lorain Steel Company without charge to the Committee and the heads themselves were purchased from the Bethlehem Steel Company which Company gave them an especially fine finish without extra charge.

Owing to the fact that it was necessary to dismantle and move the Emery Testing Machine to its new quarters, only a few of the tensile tests have been completed. Testing will be resumed as soon as the machine is reassembled in its new location.

Several trial tests were made on joints not included in the investigation to determine the action of these heads under load, as it was anticipated that some difficulties would develop in the testing. The results of these trial tests indicated that the specimen while subjected to a direct tensile stress was also under a bending stress. The cause of this additional bending stress may be due to any or all of the following causes:

1. The lack of initial straightness of the joint. In other words—lack of alignment of rails before welding.
2. Twisting of the rails due to heating during welding.
3. Slippage of the wedge grips in the holding heads which would cause a shift in the application of load in relation to the center of gravity of the specimen.
4. Lack of coincidence of center of gravity of rail section and completed joint section. This would give rise to bending stresses at the joint, as the holding heads and grips were constructed so as

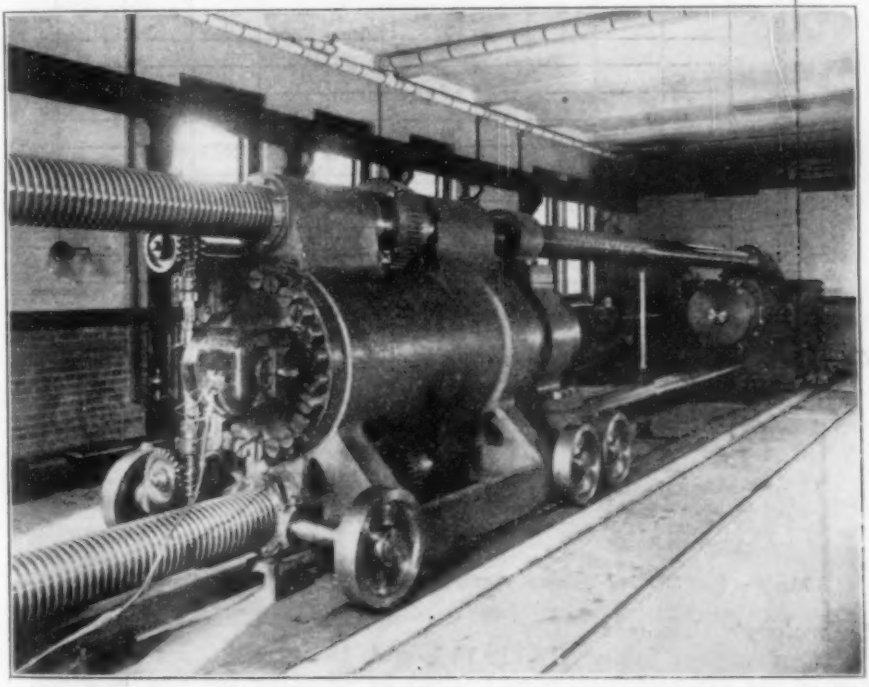


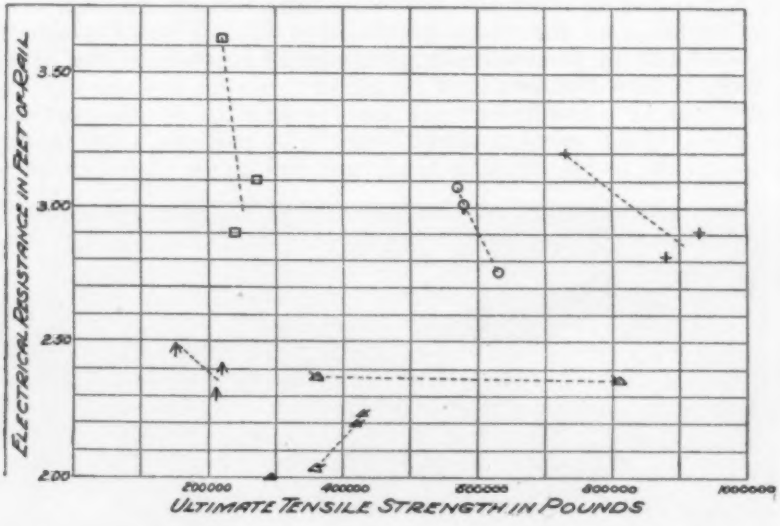
Fig. 2—Emery Testing Machine Used by the Bureau of Standards to Make Tensile Tests on Rail Joints.

to cause the line of pull to coincide wtih the center of gravity of the rail section and not the joint section. The center of the gravity of the joint varies with the different types of joints.

It seemed probable, therefore, that strain gage measurements would be necessary to help explain the results that might be obtained from tests with such eccentricities, and for that reason strain gage measurements are being made on all specimens. The tests made so far indicate that the design of the heads is entirely satis-

factory and the strain gauge measurements show that the troubles anticipated have not developed.

The methods of test adopted follows: The specimen was first examined for initial straightness and any apparent defects in the weld. The joint was then placed in the testing machine and the gripping wedges carefully adjusted so as to cause the line of pull to coincide with the center of gravity of the rail section. Load was then applied in increments of about 20,000 lbs. and strain gage measurements made for each additional load.



SYMBOLS SHOWING TYPE AND IDENTIFICATION NUMBER OF RAILS

↑ APEX 22
\+ BUTT 11
□ CAST 18
△ SEAM 4
△ SEAM 8
△ SEAM 16
○ THERMIT 12
○ THERMIT 15

Fig. 3—Chart Showing Ultimate Tensile Strength of Specimens and Conductivity

Laboratory's Comments

Cast welded joints (18-12, 18-1 and 18-5) first showed separation of the rail ends and finally failed by breaking the cast material. Slag inclusions were found under the rail flange and head.

The butt welds (specimens 11-28, 11-14 and 11-16) were found to be perfectly clean and welded over the entire rail section, the fractures having a crystalline structure. Specimen 11-14 developed the yield point of the rail material.

In seam welds specimens No. 8-5, 4-1 and 8-8 the failures occurred by the shearing of the weld at contact of fish plates and rail. Specimen 4-1 had four bolts through fish plates and web; the remaining joints were without bolts.

The seam welded joints having the Abbott plate reinforcements (specimens 16-8, 16-6 and 16-12) failed by breaking in the rail section at or near the end of fish plates.

Failures of Apex joints (22-12, 22-7, and 22-11) occurred by shearing of bolts and welds. Lengths of two to four inches of weld were found to show no fusion with the rail section.

The thermit welds (12-3, 12-5 and 15-26) showed blow holes and slag inclusions. Attention is called to the fact that the inserts in all the welds tested were not fused. Slag was found to be trapped under the inserts. The failure began by separation of the rail heads at the unwelded insert.

BEND TEST

In making the bend tests two Riehle testing machines, one of 300,000 lbs. capacity and the other of 200,000 lbs. capacity, were used. The 300,000 lbs. machine was used in making the tests on the 13 and 18 cast-iron series, the 12 and 15 Thermit series and the 11 butt weld series of joints. The other joints were tested on the 200,000 lb. machine, which is somewhat easier to use. The photograph shows the test being made on the 200,000 lb. machine. The laboratory states that the machines were both carefully calibrated and the results are correctly comparable.

In making the tests the test specimen was placed on two supporting knife edges, so that the joint was midway between the supports, the knife edges having 1¼" round edges were spaced to give a span lenght of 42". Load was applied by a knife edge resting on the saddle block, as shown in the photograph. The number of load increments was such as to give from 10 to 20 points on each joint. The deflections at the middle of the joint were taken by the use of a deflectometer reading to .001 of an inch. The deflectometer was placed upon a saddle whose ends rested upon the knife edges, The deflection readings were taken for the load increments.

Laboratory's Comments

In cast welds 18-3, 18-7 and 18-10 flaws and air holes appear in cast iron at web and flange. In 13-10 sudden tension failure occurred thru sides of casting even with bottom of flange. In 13-4 and 13-12 sudden tension failure took place thru sides at one end of casting even with bottom of flange.

The butt welded joints 11-31, 11-32 and 11-33 fractured suddenly at weld.

In the Apex joints the seam opened up in specimen 22-4 at a a load of 50,000 lbs. The failure occurred by one bolt shearing which allowed both side plates to bend and slip along web. In specimen 22-5 the bolt sheared at 25,000 lbs. and the seams opened up at 50,000 lbs. and both side plates yielded at a load of 60,000 lbs. Failure occurred by both bolts shearing and allowing plates to slip along web. In specimen 22-6 at a load of 72,000 lbs. bolts sheared and lower seam opened up. The load was again applied and at a load of 62,000 lbs, the seams opened up and side plates yielded. In specimen 9-7 a sharp crack occurred at 17,000 lbs. At load of 55,000 lbs. both sides plates yielded. At a load of 65,890 lbs. the end seam of narrow plate opened up. In specimen 9-8 at a load of about 70,000 lbs. the seam at end of plate opened up. In 9-9 a crack

occurred at 18,000 lbs. and at a load of 55,000 lbs. the end seam of wide side plate loosened up.

In the electric seam welded joints specimen 15-5 scale fell off side plates at 110,000 lbs. when test was discontinued the seams at one end of both plates opened up at head and flange. When a deflection of 5.0" was reached, the larger side plate failed in tension

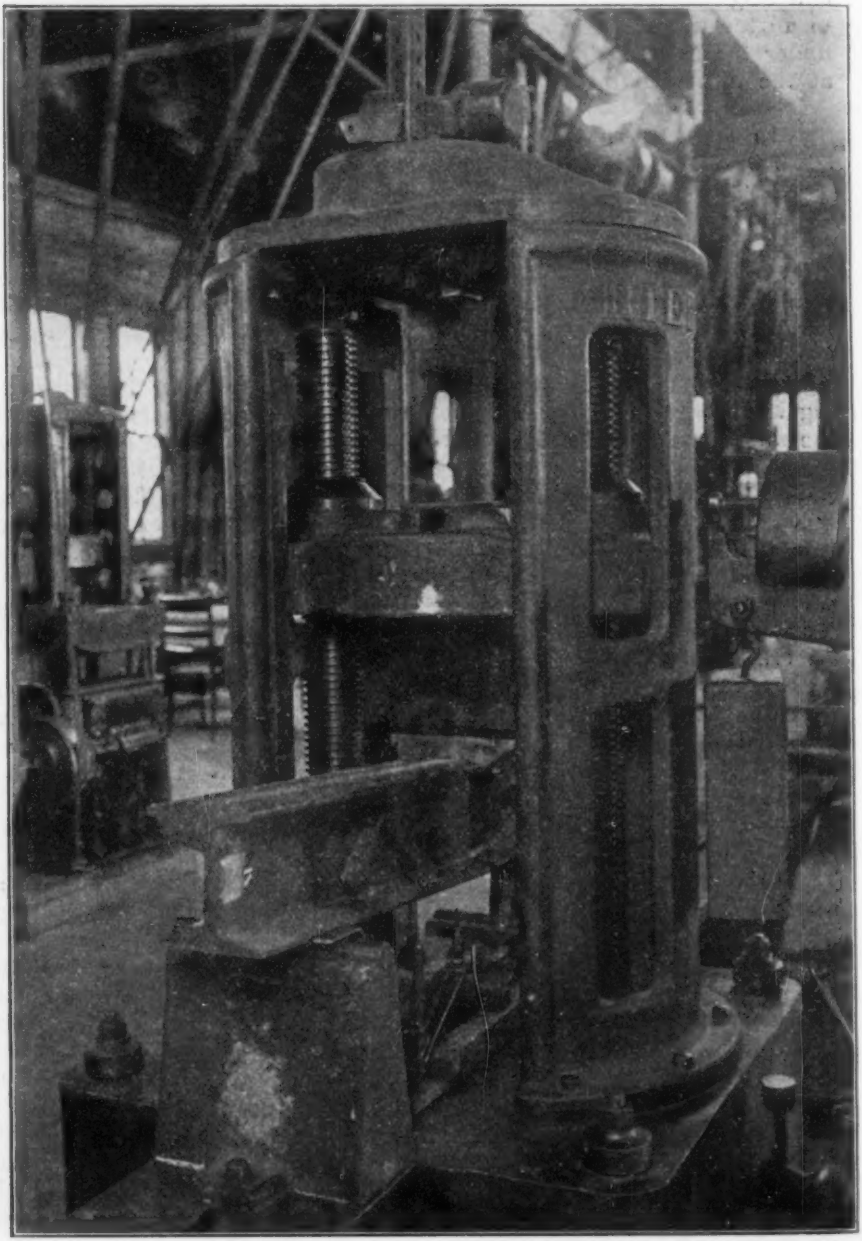
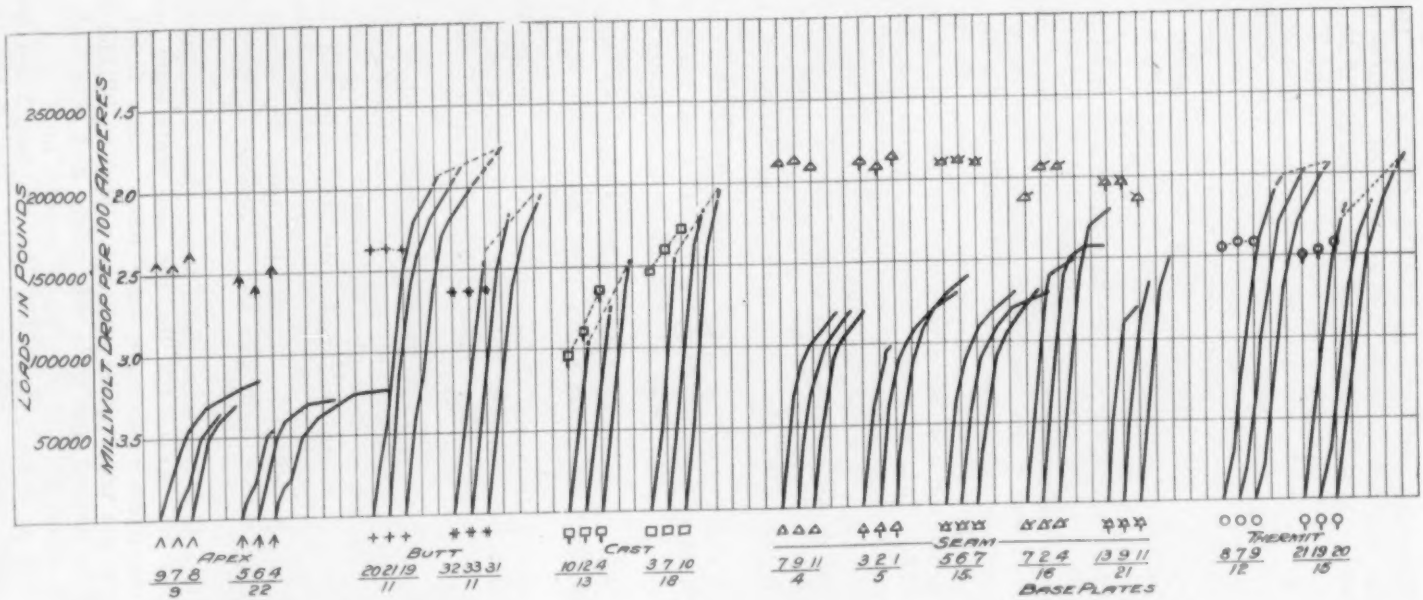


Fig. 4—Making Bend Tests on Rail Joints



HEAVY LINES ARE DEFLECTION LINES
SCALE OF DEFLECTIONS - 10 DIVISIONS = 1 INCH

SYMBOLS GIVE VOLTAGE DROP IN 3 FEET.
POINTS OF ARROWS AND CENTERS OF OTHER SYMBOLS
ARE AT POINTS PLOTTED

Fig. 5—Results of Bend Tests and Conductivity

at joint. In 15-6 the scale fell off side plate at 100,000 lbs. Seams at one end of both side plates opened up at head and flange when test was discontinued. In 15-7 scale fell off side plates at 110,000 lbs. Seams at one end of both side plates opened up at head and flange.

In specimen 21-9 a crack occurred at 70,000 lbs. load and also at 138,000 lbs. At this latter load the lower flange fractured 8¼" from joint and at end of lower plate welding. Pressure was again applied and at 120,000 lbs. a sudden crack occurred and the rail opened up between end and next bolt holes; the side plates bent and continued deformation caused tall side plate to fail thru middle bolt hole nearest to cracked rail.

In specimen 21-11 at 153,000 lbs. the base plate seam weld opened up at one end. Pressure was again applied and at 124,000 lbs. there was a sudden crack. The short side plate broke thru inner bolt hole on opposite end from seam weld failure. The large side plate failed thru corresponding bolt hole with small side plate.

In specimen 21-13 a crack occurred in the lower flange at 110,000 lbs. load at end of base plate weld and on one side of large size plate. At 131,000 lbs. a crack opened up across the flange. Upon continued application of load the rail failed between end and inner bolt holes extending thru the web and head.

In specimen 4-7 at 90,000 lbs, both plates opened up on lower edge of joint. At 104,000 lbs. there was a crack. At 130,000 lbs. the wide side plate failed at joint and lower flange failed at end of bolt hole.

In specimen 4-9 there was a crack at 102,000 lbs; both side plates splitting on lower edge at joint. At 128,000 lbs. there was a sudden failure 11½" from joint at end of bolt extending clear thru rail.

In specimen 4-11 there was slight crack at joint in narrow sideplate at 90,000 lbs. At 126,000 lbs. wide side plate failed at joint.

In specimen 5-1 bottom seam of both plates opened up at joint at a load of 100,000 lbs. Sudden failure at maximum load. Rail flange fractured at end bolt. Small splice plate fractured through center bolt.

In specimen 5-2 bottom seam of both plates opened up at joint at a load of 90,000 lbs. Sudden failure at maximum load. Small splice plate fractured at one of the center bolt holes.

In specimen 5-3 at a load of 68,000 lbs. the rail split thru flange from end of and on the side and next to small side plate. Seam opened up at end of side plate. At 108,000 lbs. there was a sudden failure thru flange at end of bolt hole and extending through web and rail head.

In specimen No. 16-2 the base plate seam yielded on narrow plate side at 140,000 lbs. At 157,000 lbs. the base plate seam opened up on the wide plate side. Both base plate seams failed at one end. When pressure was applied again at a load of 140,000 lbs. scales fell off on both narrow and wide side plates and at a load of 145,000 lbs. the top seams of both side plates opened up.

In specimen 16-4 at a load of 175,000 lbs. the base plate seam on narrow side plate yielded. The base plate seam failed at a load of 180,000 lbs.

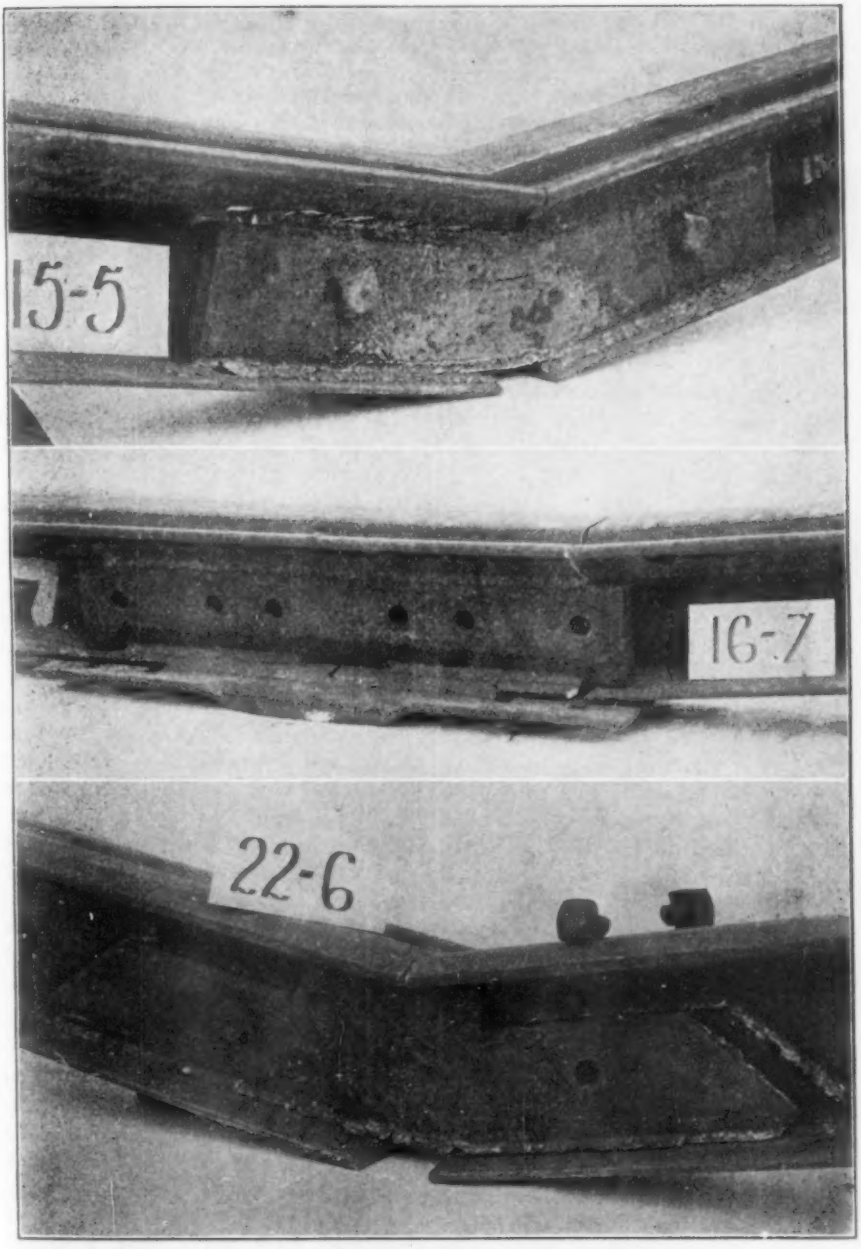


Fig. 6—Specimens Broken by Bend Test

In specimen 16-7 at a load of 127,000 lbs. a sharp crack occurred and flange of rail split at one end of base plate seam about 7½" from joint on narrow plate side. At a load of 142,000 lbs. the flange cracked clear across 6½" from joint. At a load of

157,000 lbs. which was the maximum load, sudden failure occurred thru entire rail section 11" from joint.

In the thermit welded joints specimen 12-7 failed suddenly through rail 7/8" from joint; specimen 12-8 failed suddenly thru rail 1/2" from joint and specimen 12-9 failed suddenly 7/8" from joint for the lower half and 1/2" from joint in the opposite rail for the upper half of the joint. Specimens 15-19, 15-20 and 15-21 failed through rail at edge of weld and 7/8" from joint; all failures of these three specimens were sudden.

DROP TESTS

The drop test machine used in making the tests by the University of Illinois conforms to the specifications of the A. R. E. A. The machine is arranged to allow a 2,000 lb. tup or hammer to fall freely from various heights up to 50 ft. The rail supports were bolted to the anvil of the machine and had a cylindrical upper bearing surface with a radius of 5". The distance between centers of the supports was 3½ feet.

Procedure.

The rail joints to be tested were placed on the supports with the head of the rail up and with the center of the joint directly under the center of the striking face of the tup. The tup was slowly raised and automatically tripped at a height of 6" above the joints. This constituted Drop No. I. The tup was then raised a short distance above the joint and the test specimens inspected so that the effect of the drop could be noted and recorded. If the joint was bent or developed a crack the extent of the deflection was measured and recorded and the joint removed and photographed. It was then placed back in the machine and subjected to the next blow. After the blow that finally destroyed the joint both ends of the specimen were photographed to show the nature of the fracture. For successive drops the height from which the hammer fell was increased by 6" until the height of 3 ft. was reached after which the increment in height was 1 ft.

Cast Welds.

In specimen 18-4 there was no deflection until the third blow. After this blow a deflection of .02" was recorded. The specimen broke at center of joint on the fourth blow. In specimen 18-11 a deflection of .08" was measured after the second blow and a deflection of .25" after the third blow. The rail broke at joint at the fourth blow without any previous sign of failure. In specimen 13-1 there was no deflection after the first blow. The specimen broke with the second blow. In specimen 13-9 there was a slight deflection after the first blow which increased to .25" with the second blow. At this blow a crack was noticeable in the weld along the side. The specimen broke with the third blow, the weld giving away along the crack. In specimen 3-14 there was a slight deflection after the second blow and after the third blow the laboratory reported the weld ruined as the rail cracked on one

side. The joint was also cracked. Specimen broke with the fourth blow. In specimen 3-4 there was a slight deflection after the second blow and at this blow the weld was loosened from the head of the rail. At the third blow the weld cracked and gave way. In

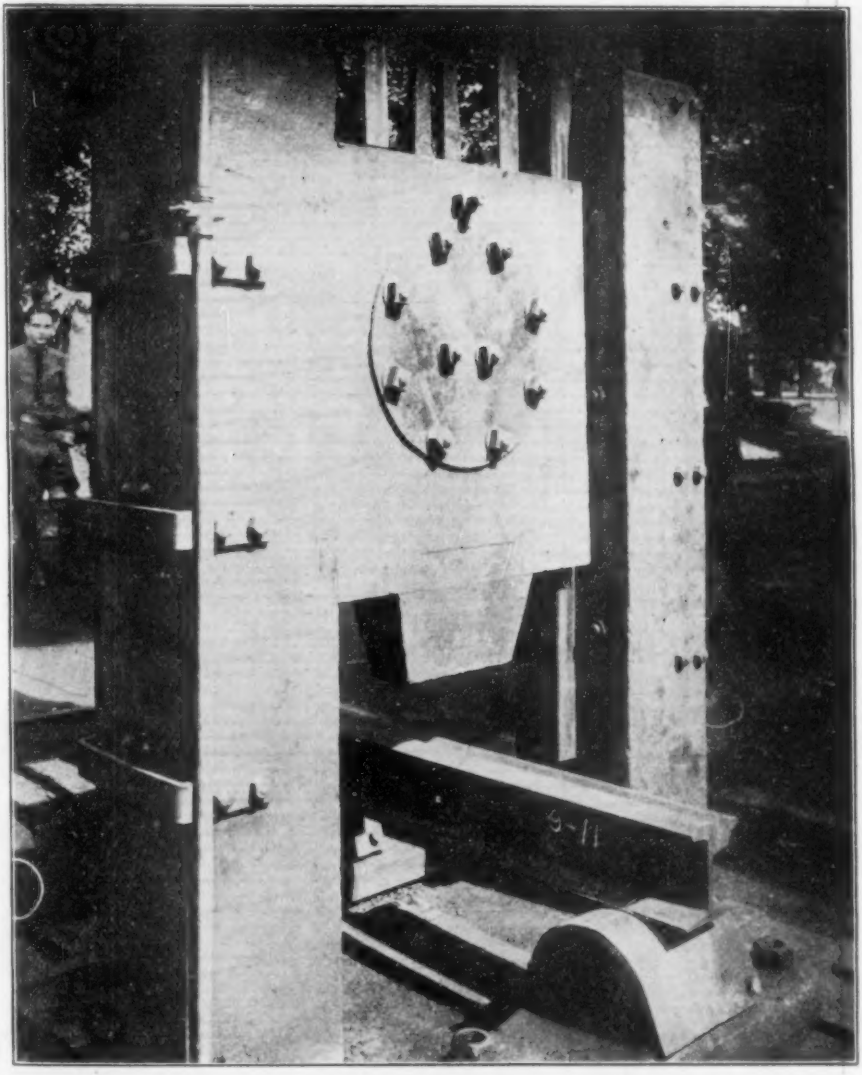


Fig. 7—Making of Drop Tests on Specimens

specimen 13-11 there was no deflection after first blow. There was a deflection of .26" after second blow with the weld cracked and joint ruined. The joint broke with third blow showing a poor weld. In specimen 3-5 there was a slight deflection after the second blow but no

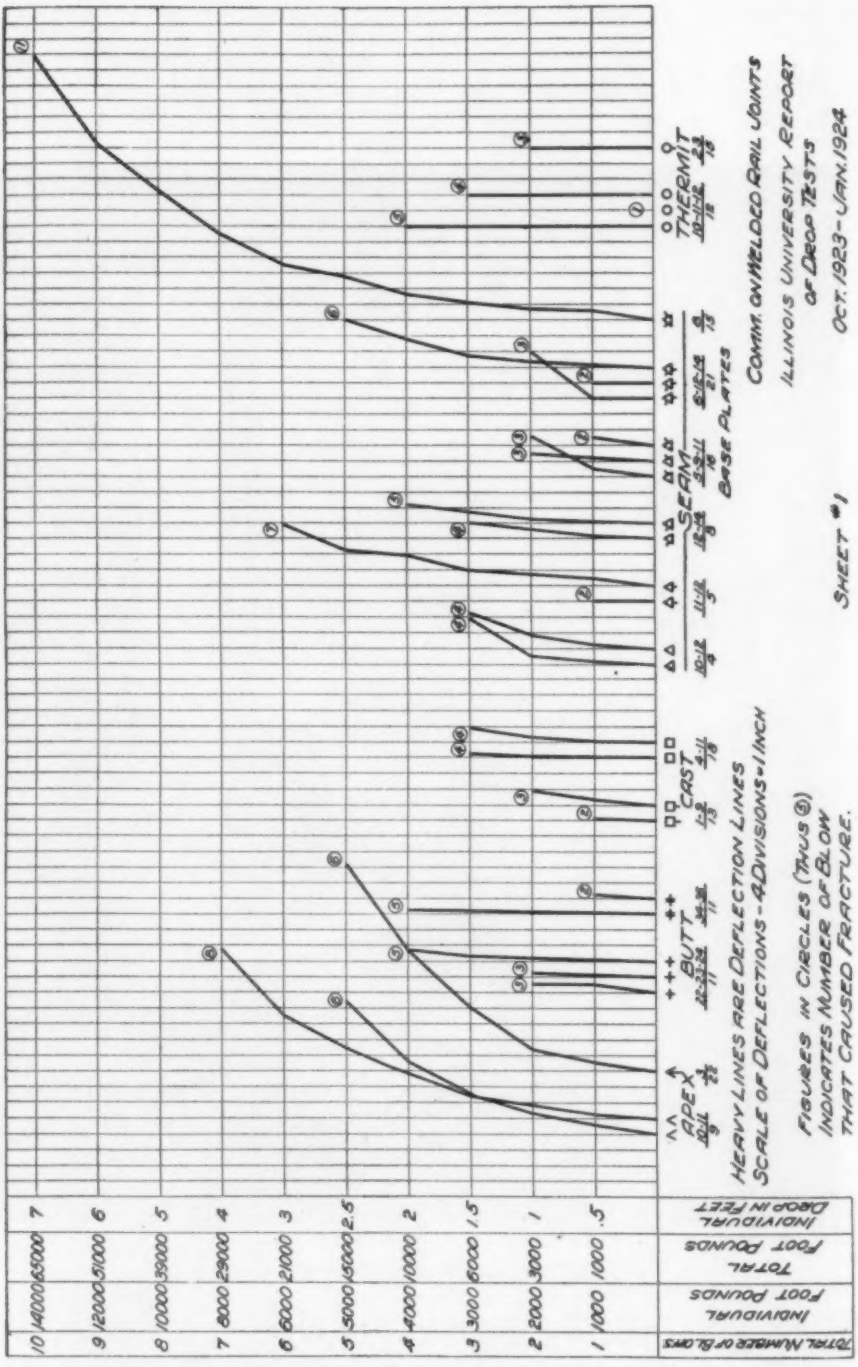


Fig. 7—Results of Drop Tests

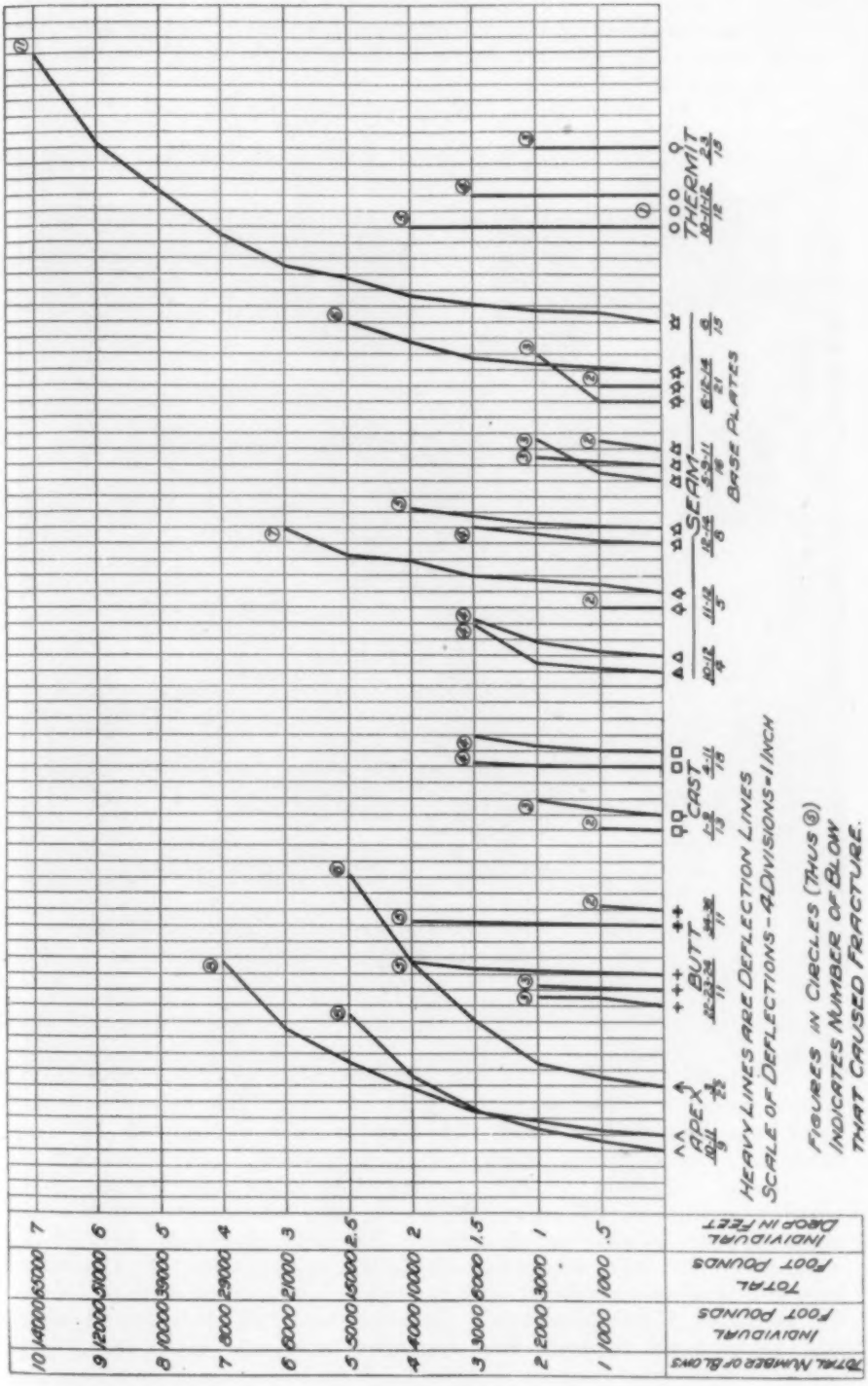


Fig. 8—Results of Drop Tests

sign of failure. The weld cracked and gave way after the third blow. In specimen 18-13 there was no deflection nor sign of failure after the second blow. The specimen broke with the third blow, revealing defects in casting.

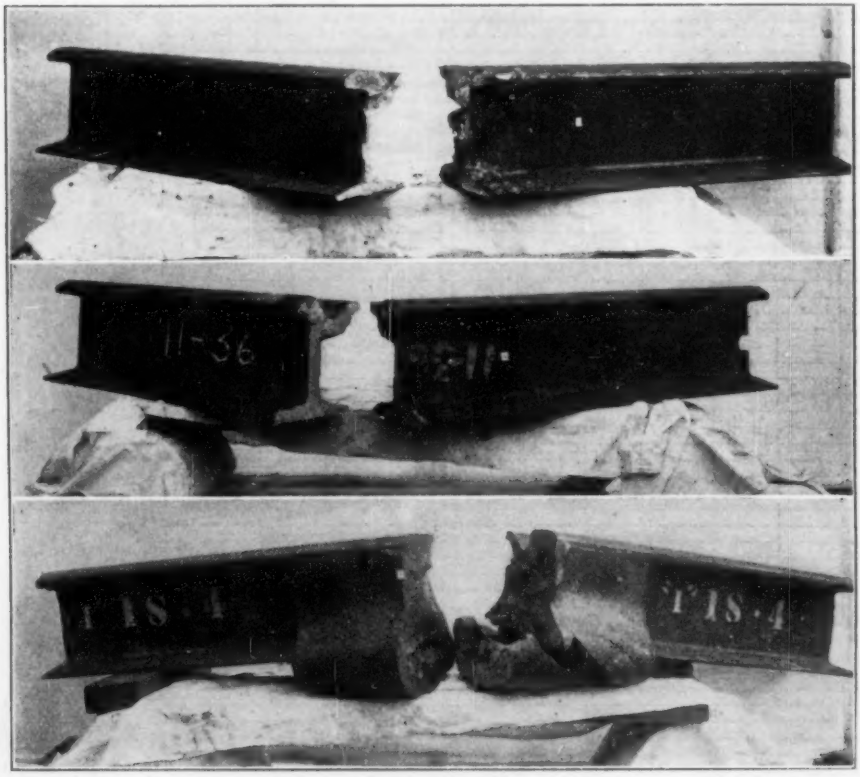


Fig. 9—Results of Drop Test. Upper Figure—Thermit Joint. Center Figure—Butt Joint. Lower Figure—Cast Joint.

Butt Welds.

In specimen 11-36 there was a slight bend after the first drop which caused a deflection in the joint of .06". The specimen broke after the second blow and the fracture was designated by the laboratory as a "clean break." In butt weld 11-24 there was a permanent deflection of 0.3" in specimen after the second blow which increased to 18" after the fourth blow although there was no sign of weld fracture at this blow. The weld broke at joint with fifth blow. In butt weld 11-22 there was a deflection of .11" after the first and second blow and the weld broke at the third blow. In specimen 11-23 there was a deflection of .05" after second blow but no sign of failure. The specimen broke at third blow thru

joint and head of rail. In specimen 11-34 there was a slight deflection on the third blow which increased to .08" with the fourth blow. At this blow there was no sign of weld failure but on the fifth blow the specimen broke. In butt weld 11-35 no deflection was noted after the first, second or third blow. The specimen broke with the fourth blow thru the weld and head of rail. The weld was good.

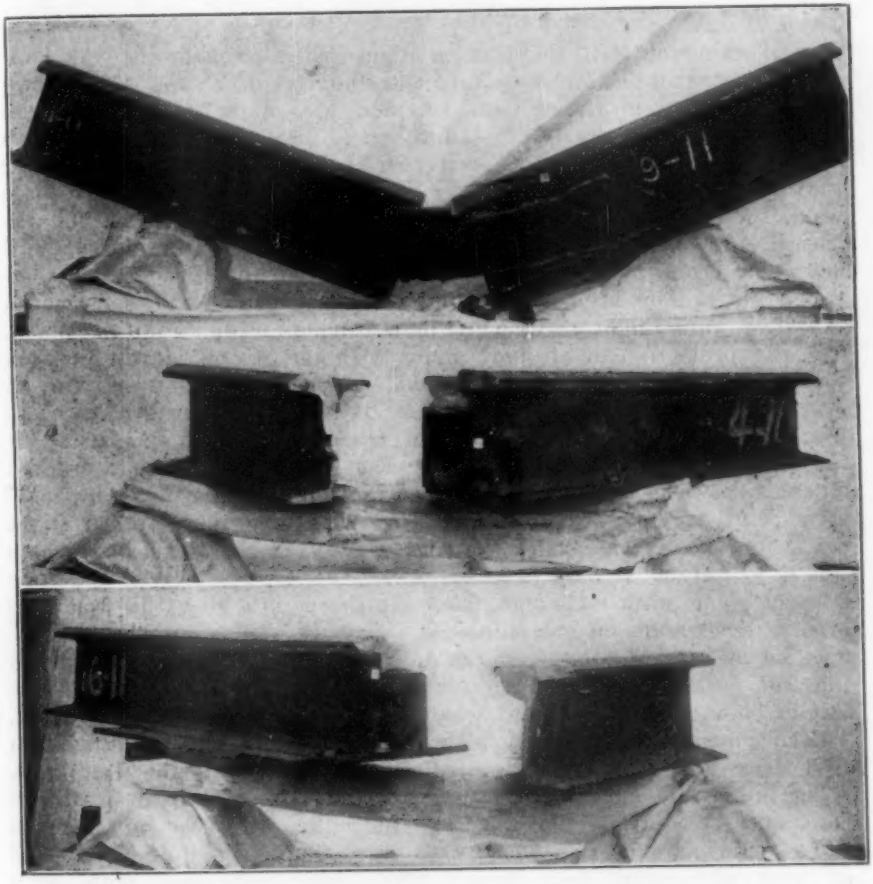


Fig. 10—Results of Drop Tests on Seam Welded Joints

Bar Welds

In specimen 6-21 there was a slight deflection after the 2nd blow and one side plate cracked. The specimen broke after the third blow. In specimen 6-22 there was a deflection of .53" after the first blow and one side plate was broken. The weld, however, was all right. After the second blow the specimen broke at joint through side plates. The welded bars were not disturbed. The weld should be classed as "poor."

In specimen 6-4 the specimen broke with the first blow showing a clean break through both side plates at joint. Poor material was in weld. Specimen 6-23 broke with the first blow showing a clean break through both side plates at joint. The material seemed hard on the outside and soft on the inside. In specimen 6-13 after the second blow one side plate was broken. With the third blow both side plates broke at joint. In specimen 6-2 one side plate cracked with first blow and both side plates broke at joint with second blow.

Seam Welds

In seam weld 4-10 there was a slight deflection after the first blow and at the second blow the total deflection was 0.11″ and a crack appeared in the weld at rail joint. At the third blow the deflection was 0.73″. The rail was badly cracked at end of joint plates. The specimen broke with the fourth blow. In seam weld 16-11 there was a deflection after the first blow of .13″ and the rail was badly cracked at end of plate weld. With the second blow the rail broke but the weld was not disturbed. In specimen 6-14 there was a slight crack in weld at joint after the second blow. The deflection increased until the fifth blow at which the rail broke at end of plates. In specimen 5-11 the rail cracked at end of joint plate with the first blow although no deflection was noted. The rail broke at end of joint plates with the second blow. In seam weld 21-14 the base of rail and weld cracked about 7″ from joint at first blow. The deflection noted was .01″. At the third blow there was a deflection of .17″ and a slight crack in seam at the base. At the fifth blow the rail cracked along seam and the joint plate cracked on one side. The deflection was .75″. The rail and side plates broke 3″ from joint at the sixth blow. In seam weld 15-8 there was a slight crack in weld at base after the first blow. At the third blow there was a ⅛″ crack at base of rail. After the sixth blow the specimen cracked along seam on flange side. At the eighth blow the weld was broken along seam on one side. At the tenth blow there was a 2¼″ opening at base of joint. At the 11th blow one side plate broke and the rail loosened between the plates. In seam weld 8-12 after the second blow there was a weld fracture at base of joints on both sides. The specimen broke at fourth blow at end of joint plate. In specimen 16-9 there was a slight crack thru weld at base after the first blow. After the second blow there was a crack thru weld at base of rail on both sides of joint. After the third blow the rail broke off near the end of side plate. In specimen 5-12 there was a slight crack in weld at base after the first blow. This crack extended with each successive blow and after the sixth blow the side plate broke on the flange side. The base of rail cracked 3″ from joint on opposite side. At the seventh blow both plates broke and also the rail. In specimen 4-12 the side plate and weld on one side cracked at center after the first blow. After the second blow the base of rail broke in two places near end of plates. At the third blow both sides were broken and the rail cracked in three places. The joint was destroyed at the fourth blow by the rail and sides breaking near joint. In specimen 21-12 there was a slight crack in weld at rail base 7″ from center after the first blow. The rail and side plates broke near joint after the second blow. In specimen 21-6 the rail base cracked 7″ on both sides of

joints. The weld broke loose from the plates on opposite side. No deflection was noted. After the second blow the rail and both side plates cracked. The specimen broke at the third blow. In specimen 16-5 the rail broke at both ends of side plates with the second blow but the weld was not disturbed. Specimen broke with the third blow. The end of the Abbott base plate was bent. In specimen 4-8 there were two slight cracks in base of rail after the second blow. The rail broke near end of side plates although the welds were not disturbed after the third blow. In specimen 10-5 the rail cracked near end of side plates after the first blow but no deflection was noted. After the second blow the rail broke near end of side plates. The seams were not disturbed. In specimen 15-9 there was a slight crack in weld at center after the first blow. After the fifth blow the seam cracked in several places and the joint was ruined. At the eighth blow the weld broke loose on most of seam. After the 9th blow the weld cracked all around; the bolts still held. After the 12th blow part of the bolts sheared and at the 13th blow the rail ends broke loose. In specimen 8-13 the rail broke at the first blow near the end of side plates. In specimen 15-10 there was a slight crack in seam at center after the first blow. The seam stretched at the third blow and gave way in several places at the fourth blow. After the sixth blow the seams loosened up in several places and the weld ruined after the seventh blow. The specimen broke at the 11th blow.

Apex Joints

In specimen 22-3 the end of rail separated after the first blow and after the second the seam cracked on base and top. After the third blow the rail ends separated at center .6". After the fifth blow the heads of rail separated .6" and the bolts sheared and plates separated. At the sixth blow the weld broke. In specimen 9-11 there was a slight bend but no sign of weld fracture after the first blow. After the fifth blow one bolt sheared and the weld cracked. At the seventh blow the weld cracked along seam on one side. After the eighth blow the rail was broken loose from the plates. In specimen 9-10 there was a slight crack at rail joint after the first blow. After the second blow the rail separated at joint. There was also a slight crack along seam at base of rail. After the fourth blow the rail cracked along seam. At the fifth blow two bolts sheared and the weld cracked and separated. At the sixth blow the rail broke at joint. In specimen 22-2 the weld cracked along part of seam after the first blow. After the third blow more of the weld cracked along seam and one bolt sheared. After the fourth blow both plates loosened from rail. In specimen 9-12 after the first blow there was a slight spread at center of base. The seam cracked on one side. The spread increased with the second blow. At the end of the fourth blow the seam loosened up on one side. At the sixth blow the spread had increased to .95" at center, one bolt had sheared and all welds loosened on one end. At the seventh blow one end of the rail broke and the weld was loose.

In specimen 22-1 there was a slight spread at center base and the seam started to crack. The spread increased at the third blow and the seam pulled loose from one side. At the fourth blow the spread

was 1.1" at center base and the bolts had sheared and the side plates loosened at one side. At the end of the fifth blow the specimen was broken although one plate was still fast to each piece of rail.

Thermit Welds

In specimen 12-10 there was no deflection or sign of fracture until the joint broke under the fifth blow thru the rail beyond the weld. In specimen 15-23 the rail broke at joint at the second blow with no measurable deflection before the break. In specimen 12-11 the specimen broke on first drop. There was a flaw in weld at rail base. The rail gave way. Specimen 12-12 broke at the fourth blow with no sign of weld failure or deflection until last blow. The specimen broke thru the weld and head of rail showing a defective weld. In specimen 15-24 there was no deflection until the 3rd blow. At the fourth blow the deflection was .1". The specimen broke with the fifth blow through the rail outside of the weld. The head of the rail was not welded otherwise it can be considered a good weld. In specimen 15-22 the deflection at the third blow was .02". The rail broke with the fourth blow outside of the weld. The head of the rail not welded otherwise it was a good weld.

CONDUCTIVITY TESTS

Early in 1923 the Bureau of Standards issued specifications for making conductivity tests on the rail joint specimens for the Committee. These specifications are given below:

Bureau Of Standards Specifications

In addition to the joint to be tested a piece of rail similar to that used in the joint to be tested will be furnished. The joint and the continuous piece of rail should be connected in series and a current of 50 to 100 amperes supplied from a storage battery through a suitable resistance. The drop of potential between points 18" on either side of the center of the joint and a similar drop between points 18" on either side of the center of the rail should be taken simultaneously with the voltmeters. (The Bureau of Standards will use meters of .5 millivolts, 1 & 2 millivolt range.) In case sufficiently sensitive millivoltmeters are not available, the readings may be taken with a potentiometer if care is taken to keep the current in the rails constant. The drop across the joint minus the drop across the 3-ft. of rail divided by one-third of the drop across the rail is the resistance due to the joint in terms of feet of rail. In some cases this will be a negative quantity.

In order that the readings shall be accurate, the following precautions should be taken:

(a) The connection of the current leads to the rails must cover the width of the web of the rail. A plate of copper attached to the current leads may be fastened to the rails by C clamps if a mercury amalgam is placed between the plate and the rail. Instead of the plate contact the current leads may be clamped to each end of the rail in three places, head, web, and base.

(b) All contact points on the rails must be bright before leads

are applied in order to avoid contact resistance.

(c) The millivoltmeters should be calibrated with the leads and clamps used for connection to the rail.

(d) In order to secure an accuracy of one per cent the test current and instrument ranges should be such that the deflections of the instruments will be nearly their full range.

(e) Immediately after the readings the current should be cut off and the positions of the meters read to determine whether a thermo e. m. f. is involved in the observations.

(f) The millivoltmeter contacts on the rails should be not less than 6″ from the current contacts and from the ends of the joints.

(g) The current in the rail should be recorded. This will permit the calculation of the resistance of the continuous rail and make it possible to compare tests made at the Bureau of Standards with those made elsewhere.

(h) The weight of the reference rail in pounds per yard should be determined and its cross section measured.

Modifications Suggested

A point was raised that Paragraph f of the above would have to be modified in certain cases because in using standard joint plates 26″ long in the seam type of weld it would leave a 5″ clear space between the end of the joint plate and free end of the rail. The Bureau of Standards replied that preliminary tests indicated that 5″ between millivoltmeter contacts and the end of the joint plates were sufficient when requirements in paragraph f could not be complied with.

Tensile Strength and Conductivity.

Owing to the fact that very few tensile tests were made on specimens before the dismantling of the Emery Testing Machine, definite conclusions as to the relations of tensile strength of the joint to conductivity cannot be drawn. The general trend of the relation is indicated by the specimens tested is shown in Fig. 3. In speaking of these tests the Bureau of Standards stated that the term "joint resistance" as used by them in their report means a total resistance over a distance of 3 feet, including the joint, and including a small portion of the rail in addition to the joint. The amount of rail included in addition to the joint varies according to the type of joint. All of these joints should be regarded as first class from an electrical standpoint in practical electrolysis testing, the only question being as to the permanency of such joints when subjected to the vibrations incident to heavy traffic over a period of years.

Bending and Conductivity.

Purdue University reports that the specifications drawn by the Bureau of Standards were followed as closely as testing facilities would permit. As an unbroken section of the rail was not available for comparison, the voltage drop over the joint was compared with that over a standard shunt by means of a potentiometer, the current being kept at a constant value of 100 amperes. The millivolt drop per 100 amperes is listed. With the butt weld joints it was possible to measure a drop over 18″ of unbroken rail. This drop multiplied by two is shown in the table below. The Bethlehem rail shows lower conductivity than the Lorain rail.

Conductivity of Rails

	Specimen No.	Millivolt Drop per 100 amps. of rail
Lorain Rail	11-19	2.42
Lorain Rail	11-20	2.36
Lorain Rail	11-21	2.42
Bethlehem Rail	11-31	2.68
Bethlehem Rail	11-32	2.70
Bethlehem Rail	11-33	2.70

KEY TO TEST SPECIMENS

Test Joint Schedule No. 1

Type of Joint	Made By	Steel from	Joint Numbers
Cast Iron	Cram	Bethlehem	3- 1 to 3-12
" "	Pinckley	"	13- 1 to 13-12
" "	Wilson	Lorain	18- 1 to 18-12
Bar Weld	George	"	6- 1 to 6-12
" "	Lorain	"	11- 1 to 11-12
Butt Weld	Lorain	Bethlehem	11-25 to 11-36
" "	Lorain	Lorain	11-13 to 11-24
Seam Weld Carbon Electrode	Clark	Bethlehem	2- 1 to 2-12
" "	Dalgleish	"	4- 1 to 4-12
" "	Estill	"	5- 1 to 5-12
" "	Graves	Lorain	8- 1 to 8-12
" "	R. W. & B. Co.	"	14- 1 to 14-12
" "	Ryder	"	15- 1 to 15-12
" "	Steward	Bethlehem	16- 1 to 16-12
" "	Wysor	"	21- 1 to 21-12
Seam Weld Metallic Electrode	Gould	"	7- 1 to 7-12
" "	Walker	Lorain	17- 1 to 17-12
" "	W. W. and M. Co.	"	19- 1 to 19-12
Seam Weld Metallic Electrode Apex Type		Lorain	
" " "	Way	Bethlehem	22- 1 to 22-12
" " "	Ind. S. & F. Co.	"	9- 1 to 9-12
Thermit Weld	Larned	"	10- 1 to 10-12
" "	M. & T. Corp.	Lorain	12- 1 to 12-12
" "	Ryder	"	15-13 to 15-24
	Candy	"	24- 1 to 24-12
" "	Lincoln	"	25- 1 to 25-12

APPENDIX A

INFORMATION FURNISHED BY MAKERS OF JOINTS

CAST WELDS

Joints Nos. 3-1 to 3-14 were made by the Brooklyn-Manhattan Transit Corporation under the supervision of Mr. R. C. Cram.

The rail was furnished by the Bethlehem Steel Company and placed in track under reconstruction where the same section was being used. The pieces were placed 8 on each side end to end making a total of 35′ 11″ of track with joints opposite as in regular practice.

The rails were cut in shop with a power saw to 4'6" lengths before placing in track. The rails were spiked to wooden ties and temporarily joined with standard splice bars and set to line and surface, ties being spaced 30" on centers for joints during welding. After placing and when track was surfaced and lined the rails including the regular new section at one end were bumped back with a rail ram to close joints. The wedges were placed at the free end adjacent to the old 9" track to secure compression.

Association standard splice bars were used for temporary joints with one, 1" diameter bolt in each joint. Each rail end had two 1-1/16"

Fig. 11—Cast Welded Joint, R. C. Cram, Brooklyn—Sand Blasting

diameter holes drilled in webs. One of them spaced 2½" from end of rail and the other 6½" from end of rail. There were also two 1-1/16" diameter holes in each rail end in bases. Steel pins 1-1/16" diameter, 3½" long having ¼" wide and ⅛" deep grooves near ends were inserted, one in each hole nearest rail ends providing two pins per joint. Joints Nos. 5 and 7 were provided with 4 pins, filling all web holes as a variation for comparative purposes.

The metal used for the casting was composed of 25% scrap and 75% pig iron. The scrap was selected, soft, machine scrap. The analysis of the pig iron was silicon between 2.50 to 3.00%, sulphur not to exceed 0.05%, manganese between 0.60 and 0.90%, phosphorus, between 0.30 and 0.85%.

Seventy-two (72) hours coke of following specification analysis was used:

Moisture not more than	0.45%
Volatile Matter not more than	2.75%
Fixed Carbon not less than	86.00%
Ash not more than	11.00%
Sulphur not more than	1.00%

Titanium Alloy was used in ladles, fives ounces for 200 lb. ladle. A high grade red fire clay was used to lute molds. The cupola and ladles were lined with white fire clay. No fluxes were used.

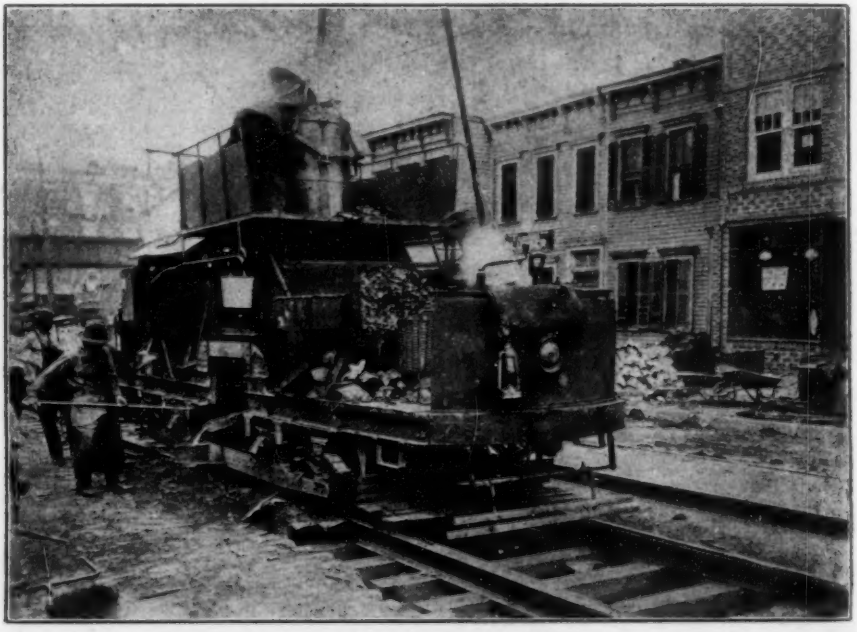


Fig. 12—Cast Weld Joint, R. C. Cram, Brooklyn—Cupola in Operation

The iron that was run from the cupola was white hot. As run from the ladles it appeared bright orange, which was probably due to effect of sunlight. Bright sparklers showed constantly in ladles as metal lowered from pouring. The metal settled quietly in molds as a rule. At one joint there was a mild gas explosion but no metal blew out. The rails were preheated with oil burner pressure torches for about ten minutes until pins showed dull red color. Heat was reapplied occasionally until molds were placed. The metal was carried in ladles by two men at an average distance of 58 ft.

The rail ends were painted with red lead after sand blasting. The molds were heated with torches for about ten minutes. The rail ends were sand blasted for the distance they were to project inside of the mold and then painted with thin graphite. After the molds were placed they were luted with fire clay and banked with sand. The molds were held in place by clamps. A heavy cast iron cap about 36″ long and

weighing about 108 lbs. which contained the pouring gate, was placed on top of the rail and held in place by hooks, bar and screw clamps. It was used to hold rails in position and conduct heat away. The iron is poured slowly with a stream of about 1½" to 1" diameter. The pouring time varied from 45 to 70 seconds averaging about one minute. The sand banks were removed from the molds about 30 minutes after pouring and the molds stripped about 1½ hours after pouring. The welds were made in the day time between 1:25 and 2:50 P. M. Average temperature was about 80°F.

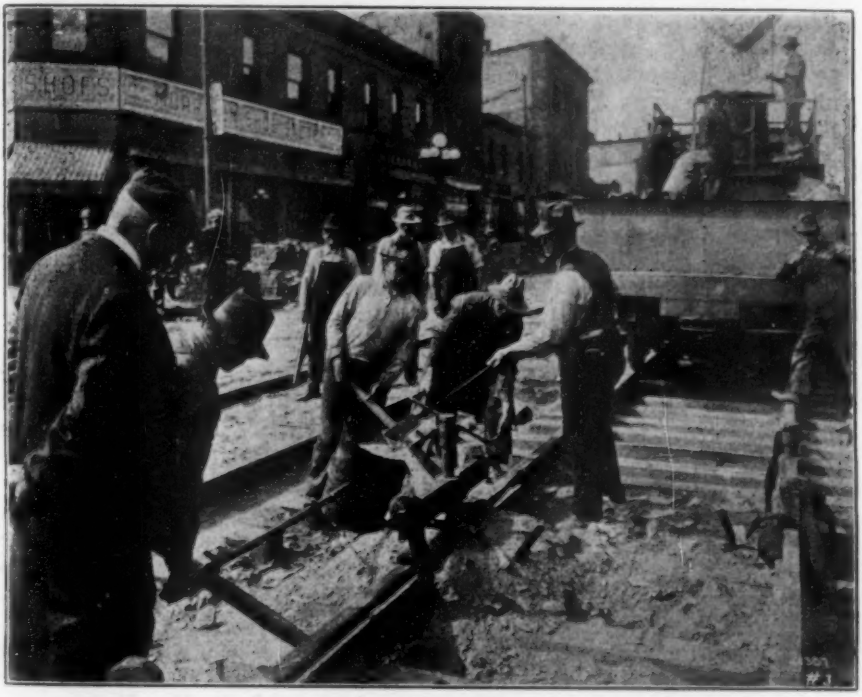


Fig. 13—Cast Weld Joint, G. L. Wilson, Minneapolis—Pouring of Joints

First 8 joints were poured beginning 1:25 P. M. and over ½ hour interval elapsed before pouring last 6 joints. Interval was occupied by pouring joints up the line in adjacent new track which allowed time for first joints to cool somewhat. Test pieces were so close that this was considered necessary. About 20 min. after each joint was poured, top screw clamps were tightened again to overcome tendency to distort in vertical plane.

Pouring Time of Each Joint

No. 1—45 sec.	No. 6—55 sec.	No.11—70 sec.
No. 2—Not noted	No. 7—50 sec.	No.12—70 sec.
No. 3—65 sec.	No. 8—65 sec	No.13—60 sec.
No. 4—45 sec.	No. 9—70 sec.	No.14—50 sec.
No. 5—55 sec.	No.10—50 sec.	

Joint No. 3 required second pouring as luting permitted first pouring to partly run out. Similar trouble at joint No. 14. Slight gas explosion at Joint No. 6.

Joints 18-1 *to* 18-12 *made by the Twin City Rapid Transit Company under the supervision of Mr. G. L. Wilson.*

The two separate rails furnished by the Lorain Steel Company were set up in the piece of track being reconstructed, placed end to end, the opposite rail being 7" plain girder section. The rails were set on tie plates spiked to standard sawed white oak ties with two spikes to each tie. The rail was surfaced and aligned in exactly the same manner as in regular track construction. On account of having a limited number of molds for this section of the rail, casting was done on two successive days. The arrangement used allowed pieces of rail 9ft. long to be welded. Temporary joints were straight plates fitting the rail with two bolts in each.

Each rail end had one hole 1-1/16" diameter drilled in it 3½" above the base and 3" from the end. In each of these holes a steel pin 1" x 3" was inserted before placing the molds.

The analysis of the pig iron used in making the test welds was silicon 3.33%, Sulphur .021%, phosphorous .117%, Manganese .92%. 40% of good machine scrap iron bought in the market was used.

The analysis (by order) of the foundry coke used was moisture 1.08%, volatile combustibles 2.35%, fixed carbon 84.92%, ash 11.67% and sulphur .85%.

No titanium or flux was used. Molders clay was used to lute joints between rails and molds. Sand was not used in the cupola.

The mixture was 60% pig iron and 40% scrap iron. The color of the metal when run into the ladles was white hot. The rails were not preheated. The ladles of hot iron were carried by four men. The distance of the test welds from the cupola was 40 to 100 ft.

Track to be welded was aligned and surfaced to the exact line and grade desired. Joints to be welded were sand blasted and carefully cleaned around the rail ends for about 10" from each end. The molds were placed in position and fastened with clamps. The caps were placed on top of the joints and fastened by hooks and screws. All joints between molds and rails were plastered with molding clay. Molds were then banked with sand and gravel. The joints were then poured and the welds left until the following day. The welding was done about 3 P. M. and molds removed about 9 A. M. Molten cast iron was brought to the joints from the cupola, a distance of about 30 to 90 ft. each ladle being carried by 4 men.

The average temperature was about 65 degrees F. Heavy cast iron mold caps were used on rail heads at joints.

Joints Nos. 13-1 *to* 13-12 *made by The Milwaukee Electric Railway and Light Company under the supervision of Mr. R. H. Pinckley.*

Two 33'6" girder rails furnished by the Lorain Steel Company were placed on the inside rail of a piece of track being constructed. These rails were spiked to yellow pine ties and supported on tie plates. The track was brought to final surface and line. Before placing in track the rails were sawed thru the head at the location of each joint and just before placing the mold the remainder of the cut was made with an acetylene torch. On account of the limited number of joint molds available it was necessary to cast eight joints on one day and six joints on the following day. Standard rolled plate joints were

used for temporary splices with two 1″ diameter bolts in each joint. Each rail end had one 1-1/16″ diameter hole drilled 2½″ from end and 3½″ above the base. In each of these holes a steel pin 1″x3″ round was inserted before placing the molds.

Analysis of pig iron was as follows:—Total carbon 3.90, manganese 0.63, phosphorus 0.444, sulphur 0.022, and silicon 2.54 per cent.

Select soft grey iron machinery scrap was used in the proportion of 25% scrap to 75% pig iron.

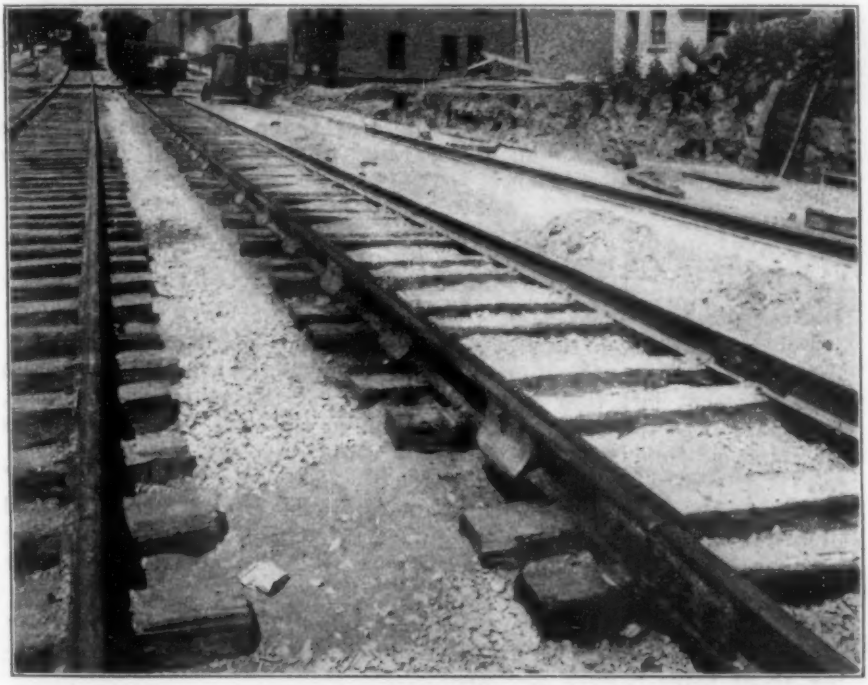


Fig. 14—Cast Weld Joints, R. H. Pinkley, Milwaukee.—Test Joints Completed

Seventy-Two (72) hour coke, of the following analysis, was used, Moisture 0.2; dry sample, volatile matter 0.80, fixed carbon 89.04, ash 10.16 and sulphur 0.43. No titanium was used. A high grade fire clay was used to lute joints between rail and molds, to line hand ladles, etc.

Flux was used commencing with third charge, at the rate of fifteen (15) pounds of crushed lime stone to each charge. This stone contained about 60% calcium carbonate.

The iron used in making the joints was run from the cupola white hot. (The metal was so hot it burned a hole thru one mold and adhered solidly to the runner cup in several instances.) Rails were not pre-heated. Metal was carried in hand ladles by four men 15 ft. to 75 ft.

Rail ends were sand blasted; pins inserted in bolt holes; molds placed and luted with fire clay and banked with sand. The molds

were held in place by a suitable clamp. A heavy cap 3′0″ long was placed over the top of the rail and hook and screw clamp installed to hold rail ends in position. The cast iron was poured slowly into the molds to allow the escape of gas. Molds were left in place until the following morning, except molds on Joint No. 2 were removed and used on Joint No. 8.

The average temperature was about 78 degrees F.

The Company states that they had not been using cast joints for the past three years. It was necessary, therefore, to set up the equipment and organize a gang especially for this job. The methods followed, however, were as nearly in conformity with the Company's former standard practice for such joints, as possible, except molds and clamps used were in accordance with Brooklyn practice.

The cast welded joints made by this Company, heretofore, have always been on tee or high girder rails, whereas the test joints were made on girder rail section.

BUTT WELDED JOINTS

Joints Nos. 11-13- *to* 11-36 *made by Lorain Steel Company under supervision of Mr. H. F. A. Kleinschmidt.*

Joints Nos. 11-13 to 11-24 inclusive were made from Lorain rail. Joint Nos. 11-25 to 11-36 were made from Bethlehem rails. Lorain rails were cut into four pieces 3′2″ long and twelve pieces 4′6″ long, and marked as to their original position in the rails. Bethlehem rails were cut as follows:—

An 11′ piece was cut into two pieces 3′3″ long and one piece 4′6″ long. Three 20′8″ pieces were cut into six pieces 3′4″ long and nine pieces 4′6″ long. The pieces were then welded together into the position they originally occupied, after which the rails were cut midway between the welds.

There was no further preparation of rail ends other then as they came from the saws. A flux of molten borax glass was used averaging about three pounds per weld.

The apparatus is mounted on two 18′ motor driven trolley cars. The first car contains a 30 K. W. alternating current generator, for supplying the welding current, direct connected to a 65 H. P. motor, an air compressor for supplying air and oil to an oil burning furnace for melting the flux which is located at the front end of the car. This car also contains tanks for air and fuel oil storage, switchboard with necessary instruments, etc., and suitable means for raising the two rail clamps from the rail and transporting them from job to job. The rail clamps are mounted on rollers at either end to which the weight can be transferred to move them from joint to joint. These clamps are provided with hydraulic pumps supplying the pressure to force the rails together in the process of welding, and means for clamping the terminals of the generator to them. The second car contains an oven for drying the cores, and a molder's bench for making the cores. At the rear end of this car two grinding machines are carried for finishing the upper surface of the rail after the weld has been made. Current for operating the apparatus is taken from the street railway

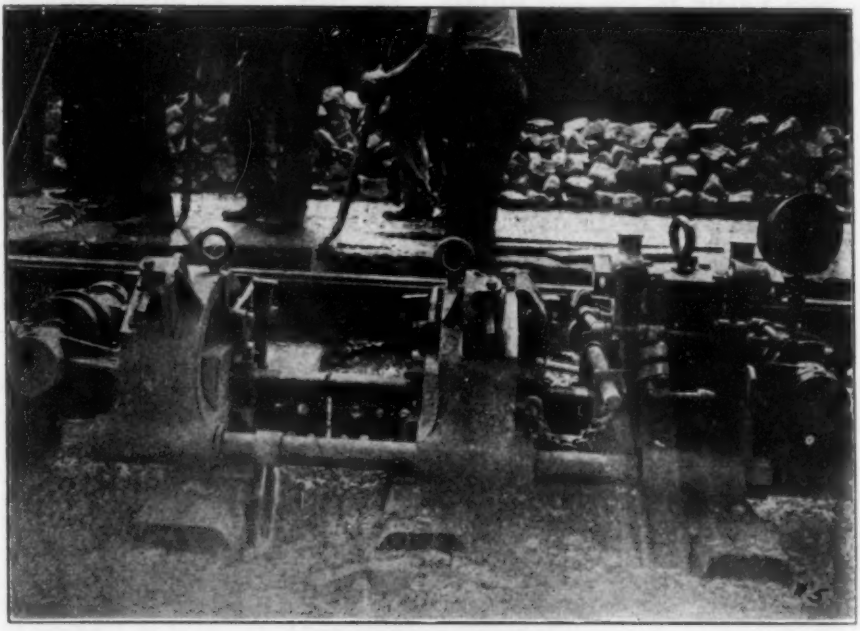


Fig. 15—Rails in Place Ready to Make Butt Welded Joint

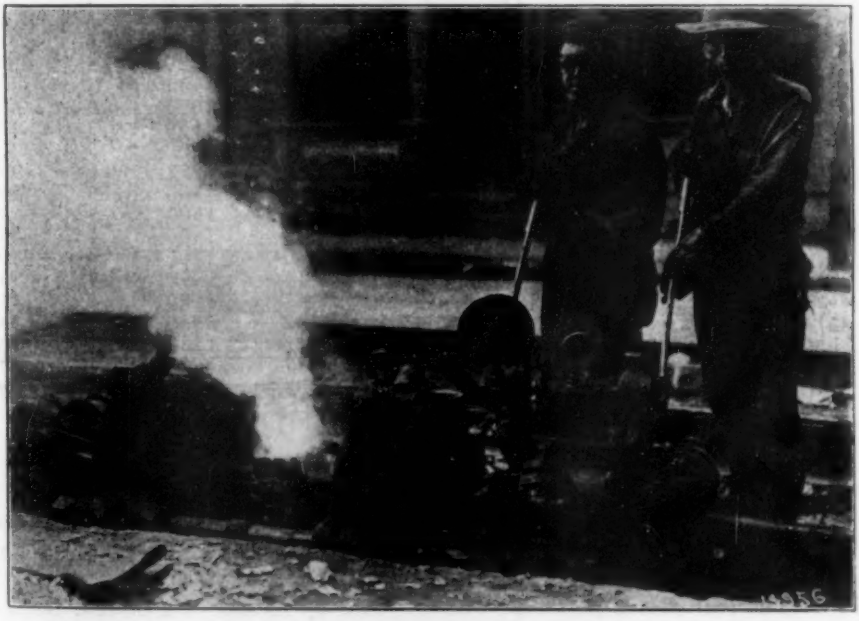


Fig. 16—Butt Weld in Progress

trolley wire. Voltage of welding current varies from 80 to 40 volts, amperage at latter voltage from 1400 to 1600.

Rail ends are confined in rail clamps by means of wedges and are

held rigidly to line and surface. The parts of the clamp engaging the rails are insulated from each other and the terminals of the generator are clamped to these parts. The rails are set with their ends about 3/8" apart preparatory to welding. Dry molds or cores, in four pieces, are set around the rail ends forming a receptacle for confining the flux so that it comes in contact with the end surfaces of the rails only. The generator is started with the voltage set at 80, the molten borax is then poured into the mold establishing a path for the current from rail to rail. In its passage the borax becomes heated more and more and the higher its temperature the greater its conductivity, so that the voltage is then cut down to 40 volts. When the rail ends reach a welding heat their resistance increases to such an extent that the voltage rises again. At this point the welding current is cut off and simultaneously the rails are forced together under a pressure of 5,000 lbs. per sq. in. This pressure is maintained for about five minutes until the metal has cooled below its critical temperature. See Table for details for each weld made.

Data Sheet of Butt Welded Joints

Joint. No.	1923 Date Welded.	Current on Mins.	Current on Secs.	Amount of Upset	Welding Volts.	Current Amperes.	Time Reheating Mins.	Time Reheating Secs.
11-21	Jan. 6	2	50	5/16"	42	1400	5	20
11-17	Jan. 6	2	30	5/16"	42	1450	5	10
11-16	Jan. 8	2	15	3/8"	42	1500	15	10
11-22	Jan. 8	2	30	5/16"	43	1550	5	50
11-13	Jan. 10	2	45	1/2"	42	1600	5	55
11-14	Jan. 11	2	35	3/8"	44	1600	4	25
11-24	Jan. 12	2	35	5/16"	42	1500	5	30
11-18	Jan. 12	2	50	1/2"	42	1500	6	5
11-20	Jan. 12	2	45	3/8"	42	1500	6	0
11-23	Jan. 13	2	40	1/2"	44	1600	5	0
11-19	Jan. 13	2	45	7/16"	44	1500	5	45
11-15	Jan. 13	2	15	1/4"	46	1650	6	45
11-28	Jan. 25	2	20	1/4"	42	1550	3	10
11-32	Jan. 25	2	20	5/16"	43	1500	5	10
11-30	Jan. 25	2	35	1/4"	42	1550	4	50
11-29	Jan. 25	2	35	3/8"	40	1500	5	30
11-36	Jan. 26	2	15	3/8"	42	1500	5	0
11-34	Jan. 26	2	40	7/16"	40	1500	4	45
11-33a	Jan. 27	2	45	3/4"	40	1700	4	10
11-27	Jan. 27	2	30	1/2"	44	1550	4	50
11-26	Jan. 27	2	40	5/8"	42	1600	4	15
11-35	Feb. 1	2	40	3/8"	42	1550	4	30
11-25	Feb. 1	2	35	1/2"	41	1500	4	50
11-31	Mar 19	2	50	3/8"	40	1600	4	20

a. Mold leaking while making this weld causing arc to form across foot of rail and melting a portion of it away.

Rails are not preheated.

The top surface of the rails at the welds is restored by The Lorain Steel Company's grinding machines built especially for this purpose. A hand grinder is used for removing any upset which cannot be reached by the machine grinder. About 15 minutes are required on the average to grind a weld..

The rail web is postheated at the weld by means of a double torch, which directs the flame against the web over the weld, from both sides at once, and an eliptic spot, about 5" long on each side of the weld and the width of the web is heated to a temperature of 1500 degrees Fahr.,

the weld then being allowed to cool off in the air. Heat is tested with a Thwing Radiation Pyrometer.

Fig. 18—Grinding Completed Butt Weld

RESISTANCE BAR WELDS

Joints Nos. 6-1 *to* 6-28 *made by Public Service Railway Company of Newark under the supervision of Mr. H. H. George.*

Joints Nos. 6-1 to 6-14 were made with Lorain rail while Joint Nos. 6-15 to 6-28 were made with Bethlehem rail.

The rails were not laid in track in street in accordance with suggestions of the Committee but were installed between the two running rails of a yard track. The rails were first bolted with standard splice bars using two bolts per joint. They were then spiked to every tie. A back-stop was formed at the southerly end by welding two bars to the webs of the running rails, then bending them in at an angle towards the track center. Against these was placed a short length of low girder rail and wedges driven between the ends of the rail being welded to prevent it from moving. The northerly end was prevented from moving by means of a track jack.

A large flaw was noticeable in the rail web when making the cut for joint No. 6-7. In making the cut for joint No. 6-24 when the cut had passed thru the rail head the rail broke diagonally thru web and base. The cut was continued thru but it was necessary to cut about ⅞ inch from the other piece of rail and jack the two ends together in order to close the joint.

The type of welding bars were about 22-⅜″ long, 3½″ wide and 1-1/16″ thick. A flux of powdered borax was used (about one tablespoon to each weld). Rails and bars were thoroughly sand blasted

and wedged to true surface. The size of the head shims depended upon the size of opening. There was no preheating or postheating. Table given below shows the electrical data taken in connection with the joints.

A Lorain Steel Company grinder was used in which the Emery wheels are carried on a carriage that slides back and forth on guides so that the movement of the grinding wheel is independent of the character of the rail surface.

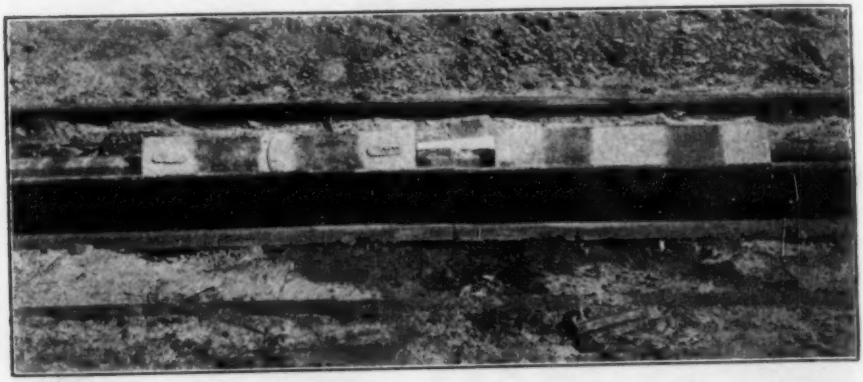


Fig. 19—Bar Weld. H. H. George, Newark. View Showing Temporary Splice Bars Removed, Rail and Welding Bars Sand Blasted.

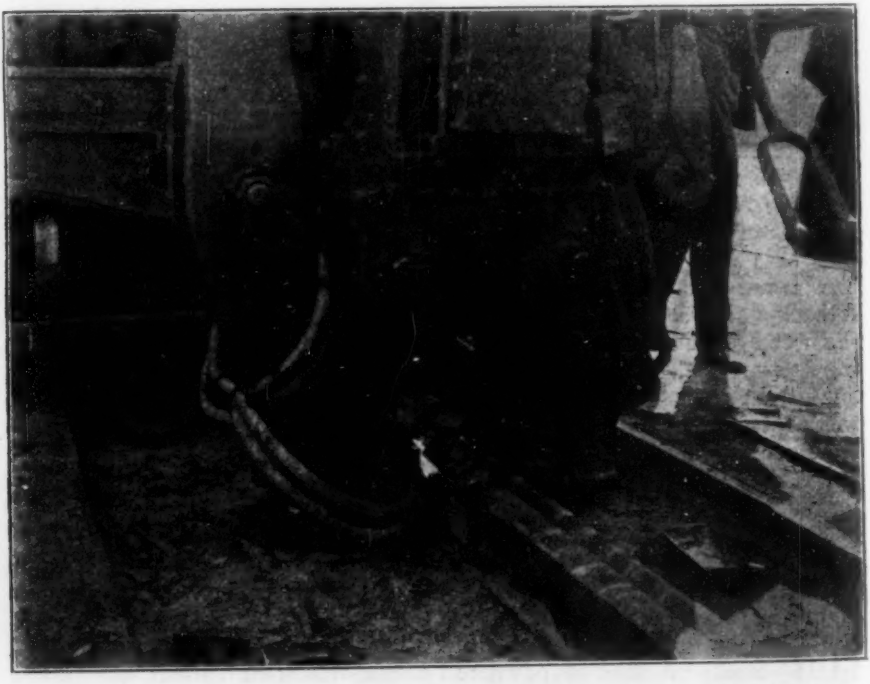


Fig. 20—Bar Welded Joint. H. H. George, Newark. View Showing Welding Equipment in the Process of Making the Center Weld.

Data Sheet Bar Welded Joints.

Sequence of welding.	Joint Number	Line No Load	Volts Alternating Full Load	Volts Alternating Full Load	Amperes Full Load	Air Temp. Fahr.	Center Weld Time Current on Sec	Outer No. 1 Weld Time Current on Sec	Outer No. 2 Weld Time Current on Sec
1	6-12	530	500	280	380	58°	470	226	216
2	6-16	525	500	285	390	58°	351	180	186
3	6-14	550	525	290	390	60°	394	149	204
4	6-15	550	525	290	390	60°	343	156	220
5	6-10	550	525	290	380	63°	334	164	204
6	6-17	550	525	290	380	63°	316	148	194
7	6- 8	550	525	285	370	64°	365	176	180
8	6-18	540	520	285	390	64°	364	195	234
9	6- 6	500	475	265	390	63°	420	164	201
10	6-19	500	475	265	400	50°	472	210	241
11	6- 4	500	475	280	410	53°	395	184	194
12	6-20	500	475	270	420	56°	460	248	222
13	6- 2	540	500	285	340	60°	420	203	250
14	6-21	540	500	285	340	62°	491	173	195
15	6-13	550	510	280	360	65°	374	194	235
16	6-22	525	475	265	390	65°	500	165	202
17	6-11	540	500	285	390	68°	360	165	187
18	6-23	570	520	290	400	72°	369	184	230
19	6- 9	540	510	280	380	72°	305	160	156
20	6-25	550	520	290	390	70°	491	173	195
			Monday, April 9, 1923, Weather, Clear.						
21	6- 5	530	490	280	400	38°	409	185	244
22	6-26	540	500	280	390	40°	384	200	204
23	6- 3	550	525	290	390	42°	390	180	220
24	6-27	540	525	290	380	44°	328	194	185
25	6- 1	550	520	285	390	50°	450	179	190
26	6-28	540	520	285	390	52°	312	183	196
27	x6-07	540	520	285	390	52°	342	183	185
28	xx6-24	530	500	280	400	52°	355	400	200

"X" Indicates rail with flaw in web.

"XX" Indicates rail which broke thru web when head was sawed through.

The rails were wedged to accurate surface and then the rail webs, welding chocks and bars were carefully sand-blasted so as to leave the surface to be welded absolutely clean. The bars and chock, or head support, were then placed in position, the bars being supported by means of small wedges laid on the rail base and being held in position by means of a wire clip until the jaws of the welder were clamped

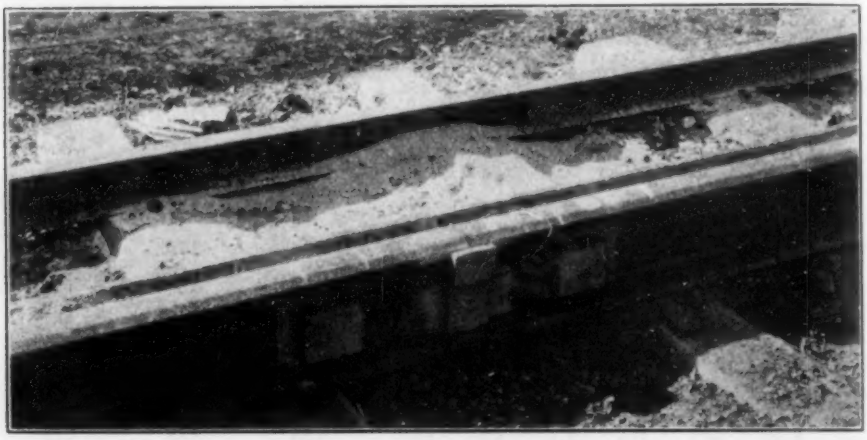


Fig. 21—Bar Weld. H. H. George, Newark. View Showing Welding Bars, Head Supports, Chocks and Shim Held in Position ready for Welding Machine.

in position. The current was turned on with a pressure between the terminals of about 7 tons. When the welding heat was reached the pressure was increased to about 37 tons at the weld. After shutting off the current the jaws were allowed to remain in position for about the same length of time it required to reach the welding heat before the pressure was released and the apparatus moved to the next weld. The amperes through the weld were about 30,000 and the voltage about 5.

(see the tabulation above for time required, weather, temperature, etc.)

SEAM WELDS

Joints 4-1 *to* 4-12 *made by the Capital Traction Company under the supervision of R. H. Dalgleish.*

The joint plates used were 1″ plates rolled by the Lorain Steel Company and furnished from the stock of the Capital Traction Company. The welding rods were 9/32″ by 24″ (grade No. 10), purchased from the Rail Welding and Bonding Company.

The analysis of the welding rod is silicon .02%, manganese 1.04%, sulphur .030%, phosphorus .005%, carbon by combustion .07%. Carbon electrode was 5/16″x12″ purchased from the Rail Welding and Bonding Company. The current varied from 275 to 300 amperes. The voltage across the arc was 46 volts. The analysis of the welding flux is as fol-

lows: Sodium carbonate 84.10%, silica .03%, iron and alumina .03%, calcium carbonate .06%, magnesium carbonate .11%, sodium sulphate trace, sodium chloride .54%, combined water 15.10%. These joints were made in accordance with our standard practice. The holes in the plates were drilled 1/16″ closer together than the holes in the rails making a driving fit for the 1″ machine bolts, which draws the rail ends tightly together. Four bolts were used, two in the center of the plate and two at the ends; these bolts remained in the joint after welding. The rail was supported on cast iron yokes 4′6″ center to

Fig. 22—Seam Welded Joint. H. M. Steward, Boston. Dynamotor-Hand Feeding of Rod in Making Seam Welds

center, the joints being suspended at the center of the span. In order to do this, it was necessary to install two temporary "dutchmen", 1′10″ long. The rail was bolted to each yoke with two 1″ bolts.

Joints No. 5-1 *to* 5-14 *made by the New Orleans Public Service, Inc., under the supervision of Mr. G. C. Estill.*

The rail was furnished by the Bethlehem Steel Company. There was no prepartion of the rail ends except cuts made with a hack saw. No base plates were used. The filler rods were 9/32″x24″ furnished by the Rail Welding and Bonding Company. As a flux soda ash was used in quantities sufficient to partially cover filler rod. No preheating, postheating or grinding was done. Order of welding was outside base seam first, inside base seam second, outside top seam third, and inside top seam fourth. The current varied from 270 to 325 amps.

Joints No. 8-1 *to* 8-14 *made by the Montreal Tramways Company*

under the supervision of R. M. Hannaford.

The steel was furnished by the Lorain Steel Company. The rails were cut with a hack saw. The plates and rails were cleaned with a wire brush. Two center bolts were used which loosely held plates in place.

Two taper pins were then inserted in outer holes and plates and driven in thereby wedging the rail ends together tightly. The center bolts were then tightened up and taper pins extracted and bolts substituted in the outside holes and tightened up.

Fig. 23—Seam Welded Joints. H. H. Da'glerish, Washington—Welding With Filler Rod in Position

The filler rod was ¼" round copper coated swedish iron having the following composition, carbon .92%, sulphur .04%, phosphorus .035%. The carbon rod was ¾"x12" with 6" taper from ¾" to ¼". No flux was used. The carbon arc process was employed, operator holding the electrode in one hand and a filler rod in the other.

No steady rest nor copper defining bar was used; two operators welding from diagonally opposite ends of the joint simultaneously, starting on the head seam. The same procedure is followed on the base seam. No preheating or post heating was used. The rails were not ground.

Joints No. 21-1 *to* 21-12 *made by the United Railways and Electric Company of Baltimore under the supervision of W. W. Wysor.*

Joint plates consisted of standard 1" plates rolled by the Bethlehem Steel Company. The welding rods were 9/32" round rods purchased from the Rail Welding and Bonding Company. Abbott base plates were used which were purchased from the Bethlehem Steel Company. On joints 1 and 2 a welding flux having the following

composition was used: borax 53.27%, bicarbonate of soda 21.00%, water of crystallization 26.73%. On joints 3 to 14 a flux of the following composition was used: carbonate of soda 76.20%, sodium chloride 0.83%, water of crystallization 22.97%. The amperes for the bottom seam varied from 175 to 225. The amperes for the head seams varied from 200 to 250. The voltage across the arc was about 40 volts. The rails used in making these joints were furnished by the Bethlehem Steel Company. The welding rods have the following composition, carbon 0.43%, manganese 0.742%, silicon 0.022%, sulphur 0.029% and phosphorus 0.004%. In making these joints standard practice was

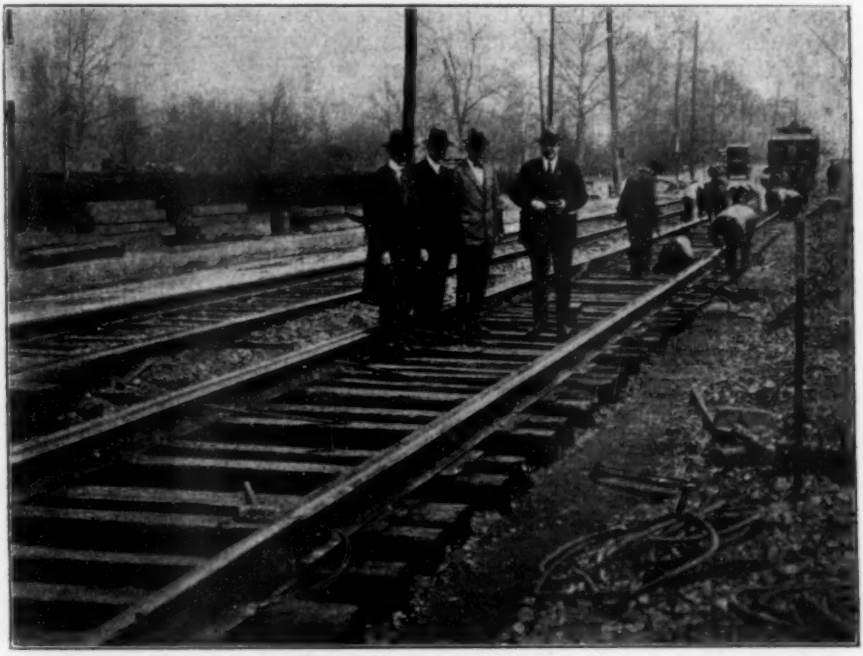


Fig. 24—Seam Welded Joint. W. W. Wysor, Baltimore. Illustrating Method of Making Joints as Specified by Committee.

followed in drawing the rails tightly together before welding. This is accomplished by having two outer holes in the joint plates punched slightly eccentric with the holes in the rail, then driving in drift pins which draw the rails tightly together. Two center bolts are then drawn up tight so as to hold the rails in this position while the welding proceeds. After the two center bolts are tightened up the drift pins are removed and bolts substituted. After the welding all bolts are removed.

Joints 15-1 *to* 15-14 *made by the Third Avenue Railway System under the supervision of Mr. E. M. T. Ryder.*

The rail was furnished by the Lorain Steel Company. The rails were sawed thru with a hack saw and wedged together tightly from next joints. No head inserts were used. The filler rods were 9/32"

diameter, 24" long furnished by the Rail Welding and Bonding Company and having the following composition: carbon .05 or less, manganese .35 or more, sulphur .003 or less, phosphorus .003 or less. The carbon electrode was 7/8" in diameter and 12" long. Pencil pointed 4" on the end. No flux was used. The welding current ranged from 225 to 250 amperes. The voltage varied from 35 to 40 volts.

The rail is butted together at joint and wedged tightly from next joint. The plates were adjusted to a mechanical fit and bolts tightened. The rail is then preheated and location of each seam cleaned with a steel wire brush and that seam welded. The sequence of welding is inside base, outside base, inside lip and outside head. No deflector bars and steady rest were used on base seam. In welding head and lip seam the deflector bars and steady rest were used. The temperature at time of welding was 40 degrees to 55 degrees F.

The preheating is done with two kerosene torches placed so that the flame impinges on web of rail about 6" from end of plate on opposite sides in a direction as nearly parallel with rail as possible. The torches are reversed from side to side every five minutes to obtain as even heat as possible. The time required to preheat is about twenty minutes. The rail was heated to about 395 degree Fah. At the ends of the plate when the flame of the torch strikes web and rail the temperature is greater, reaching a deep blue color. No grinding was required on these joints as sawing thru the rail and wedging the saw kerf tightly together results in an unusually smooth joint which was only polished off. No post-heating was used.

This welding was done in an asphalt paved street. The paving was cut away about 15" outside of the rails to make room to work in.

Joint Nos. 16-1 *to* 16-12 *made by the Boston Elevated Railway Company under the supervision of Mr. H. M. Steward.*

The rail was furnished by the Bethlehem Steel Company. No special preparation was made of rail ends. Abbott base plates were used. The joint plates were 1" machined plates made by the Bethlehem Steel Company. The filler rod was 9/32"x24" furnished by the Rail Welding and Bonding Company and having the following composition, carbon .10%, manganese .92%, silicon .03%, sulphur .040% and phosphorus .005%. The electrodes were graphite rods, 1/2" round. No flux was used. The amperes were about 140. The method of welding consisted of the operator holding the rod in one hand and the electrode in the other. About one hour is required for each joint. No preheating or post-heating is used. The joint is ground for about 5 minutes with a Universal type of grinder.

In making these joints the practice was used of placing a 1/16" insert of slightly softer composition than the rail between the ends of the rails and forcing the rails tightly together so that the head of the rails are under compression. In this particular case this was accomplished by leaving a gap between the end of the test rail and the permanent rail of the track. A wedge was inserted in this gap and when the joint cuts were made and the insert in place the rails were driven tightly together by the use of the wedge. The joint plates

were full bolted. The rail joint base plates were spiked in place. In making the welds approximately 1½" welding rod was used per lineal inch of the seam weld. After the joints were welded the bolts were removed.

THERMIT WELDED JOINTS

Joints No. 12-1 *to* 12-12 *made by the Metal and Thermit Corporation under the supervision of Mr. J. H. Deppeler.*

The rails were furnished by the Lorain Steel Company. The molding material used was manufactured by the Metal and Thermit

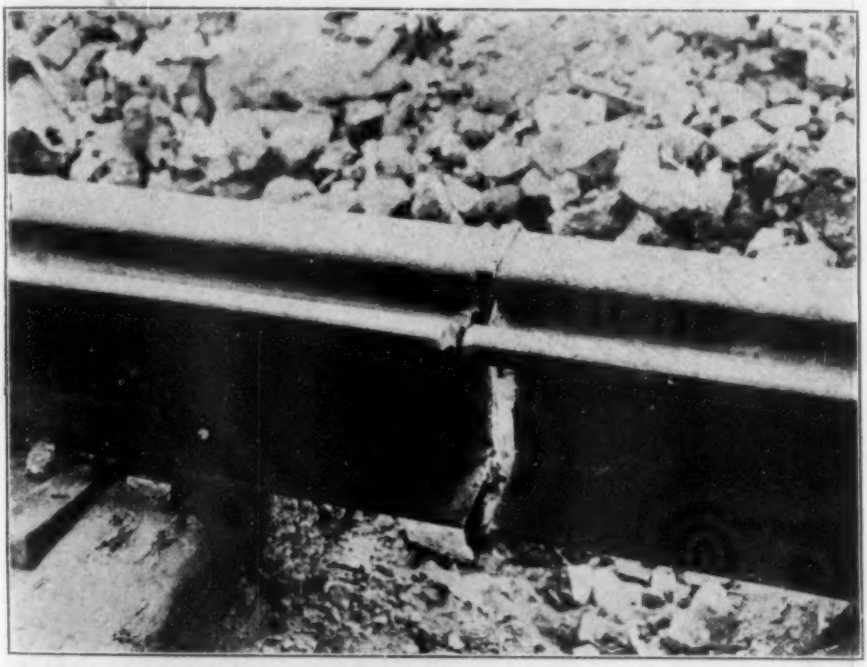


Fig. 25—Thermit Joints. Insert Wedged Between Rail Ends—Grove Rail

Corporation. This consists of sharp silica sand mixed with a minimum account of plastic clay and a small amount of glutrin. Regular No. 13 C. P. rail welding portion of Thermit was used. The molds were rammed by hand on aluminum patterns and in self-luting mold boxes. The two half mold boxes were clamped together on the rail with regular square clamps and the joint preheated by means of a light weight single burner preheater using kerosene. The heating gate was plugged with metal cup plug and the back vents with regular taper pin back gate plugs. The rail ends were thoroughly scratch brushed and inserts carefully fitted. Eleven joints were welded the first day and the remaining three finished the next day. The total time required was eight hours. The temperature on the first day was 63 degree F and on the second, 72 degree F. The preheating time

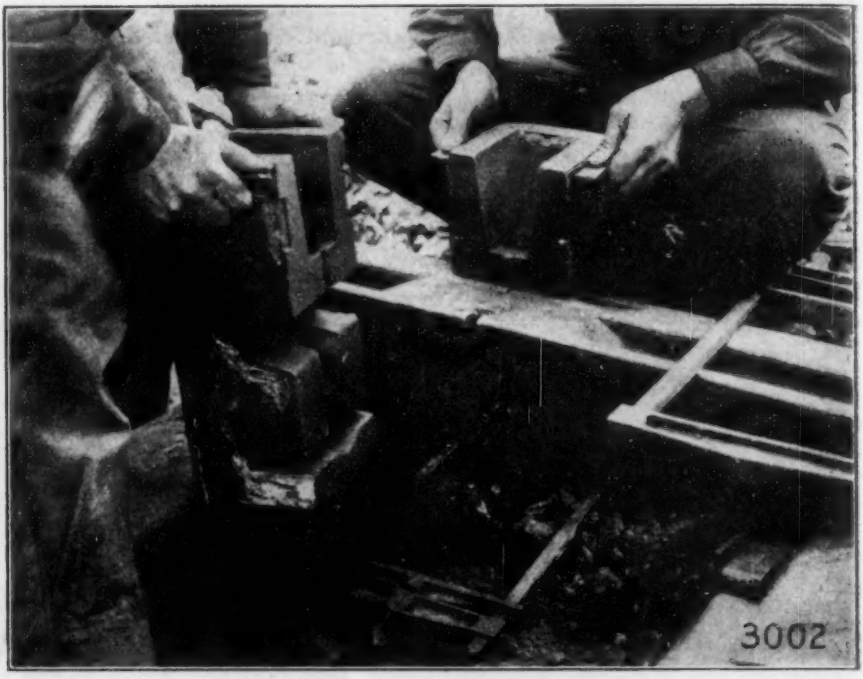


Fig. 26—Thermit Joints. Putting Mold Boxes in Place

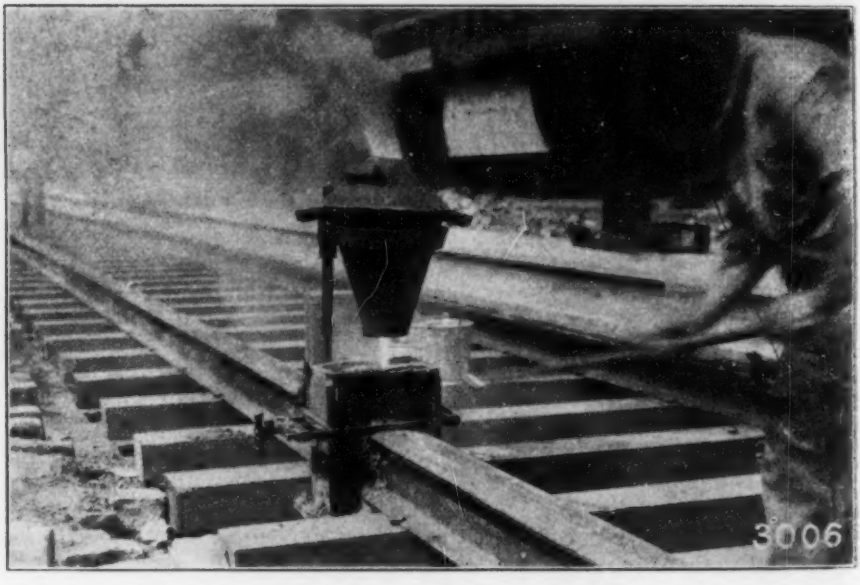


Fig. 27—Thermit Joints. Pouring the Steel After the Thermit Reaction

varied from 20 to 30 minutes per joint. Temperature was about 1600 degree F. No post-heating was used.

As only a few joints were required the universal grinding machine on hand was made use of. No effort was made to either speed operation on grinding or welding.

Joints No. 15-15 *to* 15-28, *made by the Third Avenue Railway System under the supervision of Mr. E. M. T. Ryder.*

The rail was furnished by the Lorain Steel Company. The molding materials were supplied by the Metal and Thermit Corporation. The rails were sawed thru head with a hack saw. The lip, web and base were cut with an acetylene torch. The rail was cut back at lip, web and base ½" and a ½" square notch cut in outside edge of head

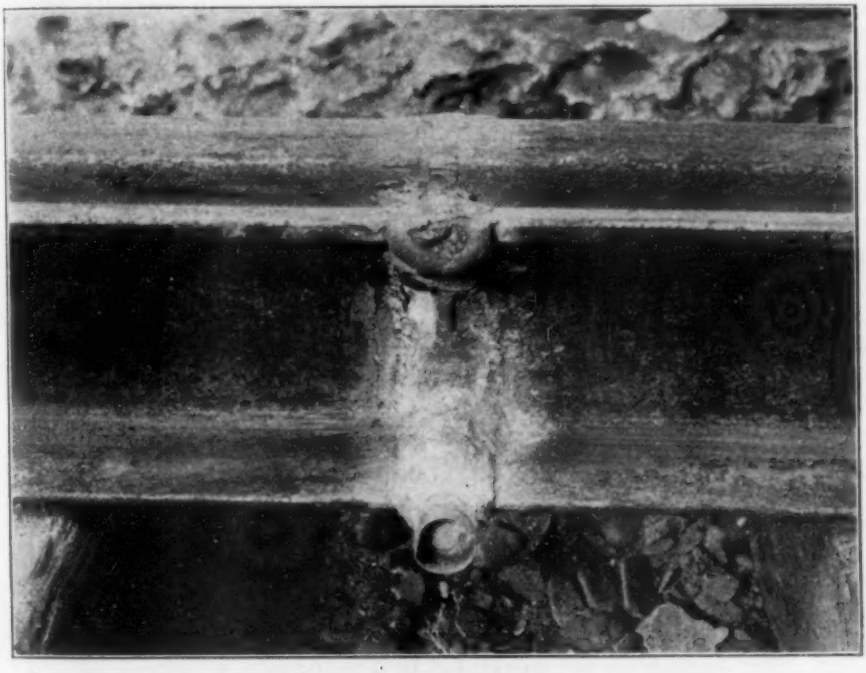


Fig. 28—Finished Thermit Joint.

under riser gate of mold. The sawed ends of rail heads were cleaned of rust and forced tightly together by wedging from the next joint. No head inserts were used. The rails were lined before putting on molds.

The molds were made by hand in steel mold boxes from cast aluminum patterns. The molds were placed on rail centering on ½" slot in web and base and clamped ready to preheat. The temperature was 55 degree F.

The preheating was done by the Metal and Thermit Corporation's power driven kerosene torch preheater in which the fuel is vaporized by passing through pipe heated by an electric coil. The time required was 30 to 35 minutes. The temperature was such that the rail was heated to bright red on all parts within the mold.

The excess steel contained in the pouring and rising gate is cut off by hammer and chisel while still red hot and the slag and sand cleared away. The time required per joint is 30 minutes. No post heating was used.

It required about 1 hour and 10 minutes to make the first joint from starting to make the mold to cutting off the riser and pouring gates. An inspection of the welds after cleaning sand and slag away revealed the following defects: No. 15-19 showed blow hole in collar on outside of web. No. 15-23 showed a small depression in head of rail about the size of a one cent piece, caused by a crack in the mold between the pouring and riser gates which allowed a wash of hot metal across the face of rail. If this joint were to be actually used in track it would be necessary to build up with metallic arc process and grind smooth. In No. 15-28 a run out occurred when pouring this joint, which could not be stopped. It carried away the outside of head and lip of rail as can be seen. It would be quite easy to replace this metal by either thermit or electric process in such a manner that the joint would give good service.

The welding was done in an asphalt paved street. The paving was cut away about 15" outside of rails to make room to work in. There were no cars operating in this street at the time welding was done.

The Committee on Welded Rail joints invites your discussion of this report and analysis of the test date. These discussions will be printed in the April issue of the Journal.

All material must be in the hands of the Secretary of the Committee by March 24, 1924.

W. SPRARAGEN,
Sec. Committee on Welded Rail Joints.
33 West 39th St.
New York City.

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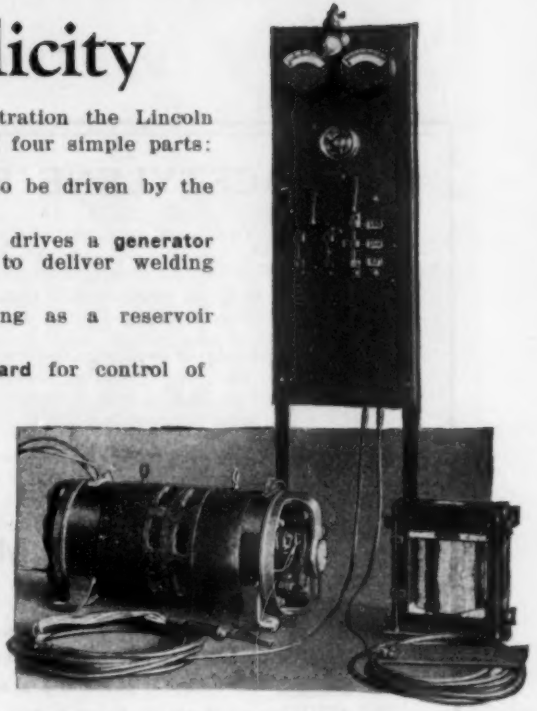

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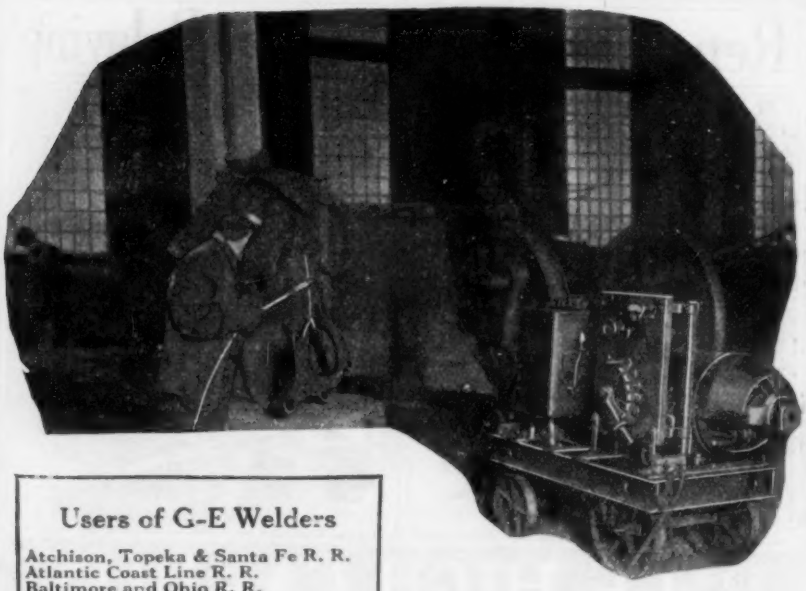

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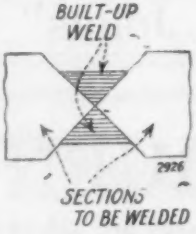

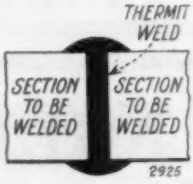

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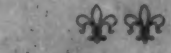

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Air Reduction Sales Company maintains its own Apparatus Repair Shop in each Airco District Office city.

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